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TEMPORARY CORROSION PREVENTIVES FOR AVIATION USES AND METHODS OF TESTING THEM.

By E. W. J. Mardles (Fellow) * and J. Mason, M.B.E. (Fellow). †

Summary.

Mention is made of the numerous temporary corrosion preventives—including corrosion-preventive lubricants—which have been used in connexion with aviation. Special features of temporary protectives are briefly discussed. Methods of test are treated in the order :—Exposure, Accelerated, Mechanical, Special Tests for Engine Corrosion Inhibitors, Other Laboratory Tests, and Norma-Hoffmann Bomb Oxidation Tests. A number of results by the last-named method are stated and discussed, and attention is drawn to the interest and importance of this method in testing and developing temporary protectives and other products.

Introduction.

Temporary protective coatings are required by aircraft constructors and users for application to the surfaces of various components during storage or transit, to prevent or minimize deterioration and consequent damage to surfaces and loss of strength. Deterioration may be caused by atmospheric corrosion, attack by corrosive vapours, mechanical abrasion and damage, attack by moulds, etc. It may also result from the use of unsuitable protective coatings or by storage with substances, *e.g.*, certain greases, erroneously assumed to have some protective effect or to be "safe" for the purpose.

Prior to use or assembly into an aircraft of the film-protected parts, the coating is usually removed by immersion in a solvent bath, by wiping clean with a rag soaked in solvent, or by the use of warm, soapy water. If moving parts are packed with a soft protective material or if engine interiors are sprayed with a corrosion preventive, it is better if the temporary protective need not be removed, *i.e.*, if it can be allowed to remain and be assimilated and replaced by the lubricant in normal use, or otherwise consumed.

Aviation Uses of Lanolin-base and other Temporary Protectives.

During the rapid development and use of aircraft in the 1914–18 war, it was found that ordinary paints, subjected to severe weather conditions and vibration, failed, mainly by flaking and lack of adhesion. This was especially the case on the original streamline R.A.F. wires.

Coatings of anhydrous lanolin tinted and hardened with a natural resin were found to be useful. Transparent coatings were preferred in those

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days mainly because the inspector and pilot could note the early development of any fracture or flaw in the component parts. With Dr Bengough's discovery of the anodic treatment of aluminium alloys and the recommendation of a lanolin wash to supplement the treatment, the use of lanolin protectives became established in aircraft practice. The idea of hardening the film, to free it from tackiness, came about because the soft film from the ordinary lanolin wash tended to collect dust in hot climates. The lanolin and neutral resin were dissolved in a mixture of hydrocarbons.

The lanolin-base temporary protectives now in use in the R.A.F. are :—

D.T.D.121D.—Temporary Rust Preventive. Solution of anhydrous lanolin in white spirit.
D.T.D.279B.—Pigmented Lanolin–Resin Solution. Pigments zinc chrome and kaolin, and solvent a mixture of SBP3 spirit and xylole.
D.T.D.420B.—Matt Pigmented Lanolin–Resin Finishes, including anti-fouling finish.
D.T.D.663.—Lanolin Resin Protective. Dyed solution of anhydrous lanolin with resin in a mixture of SBP3 spirit and xylole.

Other interesting temporary protectives are used in the R.A.F. for preventing internal corrosion of piston-type engines during storage after running. These preparations are :—

D.T.D.587.—Engine Corrosion Preventive (corresponding to U.S. Specification AN-VV-C-576a, but requiring presence of lead-free petroleum spirit).
D.T.D.791.—Engine Cylinder Protective (Wax Thickened).
D.T.D.698.—Storage Oil (corresponding to U.S. Specification AN-VV-O-576b).

The corrosion inhibitor mentioned in each specification has to be approved by R.D.Mat.(NM.). The specifications do not include detailed composition requirements for the additives, so they may or may not contain lanolin. These corrosion preventives are different in that they must have special qualities in order to combat the effects of the combustion products of fuels, including leaded fuels. The first two are used for spraying into engine cylinders, and the third is used in lubricating-oil systems. Their use, prior to or during storage, is combined with suitable periods of running on lead-free fuel (D.Eng.R.D.2483). It is of historical interest that the specifications preceding D.T.D.587 (January 1944) were E.G.174, D.T.D.437 (September 1940)—Corrosion Inhibitor, Lard–Oil Base, and D.T.D.555 (April 1942)—Lanolized Oil. Full details of E.G.174, developed by the Ethyl Gasoline Corporation, are given by F. R. Banks (*J. Inst. Petrol. Techn.*, 1937, **23**, 95, 131).

There was a specification, D.T.D.561, Corrosion Inhibiting Instrument Oil (July 1943), but this is now obsolete.

Apart from D.T.D. specification materials, many other temporary protectives have been used for the protection of metals and aircraft and engine components. During the last war lanolin was in short supply, and had to be conserved for particular uses. Efforts had to be made to replace it by hard, neutralized wool-grease (D.T.D.680), and this was done in D.T.D.663

and D.T.D.279B. The approval of certain lanolin-containing proprietary materials had to be withdrawn for this reason, but quite a number of new preparations were approved, and in these much ingenuity was shown in avoiding the use of lanolin. In this period of development full recognition was given to the valuable properties of mineral jelly (D.T.D. 55 or C.S.1317B) and mineral jelly-beeswax (C.S.2296). Among the new proprietary preparations there was a Dewatering Oil. This was for the same purpose as U.S. Bushipe 52-C-18 Grade III (Tectyl 511). It is capable of displacing water from wet surfaces and depositing a protective solid film. It was used for coating the interiors of some steel storage tanks for care-and-maintenance purposes, and performed well. The position regarding lanolin is not now so difficult, and there has recently been an approval of a proprietary material containing lanolin for use with engine cylinders prior to treatment with D.T.D.587 or D.T.D.791.

Certain C.S. specification materials, in addition to C.S.2296, have also been used for preserving aeronautical materials. C.S.1663—Composition, Preservative, Spraying—was approved as an intermediate preservative for use on non-ferrous and light-alloy parts, but with changes in this specification, and the use of "overall" markings, it is being replaced for this use by D.T.D.804 (85 per cent mineral oil and 15 per cent lanolin D.T.D.122B). C.S.2298B is Preservative for Metal Components containing Rubber. Discussion has taken place as to whether D.T.D.663 and C.S.1033D (now E) are both necessary for service use, and it has been decided that neither of them could be dispensed with. There is a Water-Displacing Fluid in the C.S. series, *i.e.* C.S.2060A.

Lubricants as Temporary Protectives.

There are certain modern greases which have bomb oxidation requirements, and materials of this kind would have claims to be regarded as temporary protectives and perhaps even more than that. It is necessary for sealed bearings to be filled initially with the operational lubricant, such as the U.S. grease AN-G-3a (D.T.D.577) or its successor AN-G-25, and there is sometimes a wish for other bearings to be similarly supplied. It is obviously necessary for lubricants to be adequate in corrosion-protecting qualities to be used in this way. AN-G-3a—D.T.D.577 grease has been reasonably successful, though it will not preserve metal parts indefinitely, and there is reason to believe that its derivative D.T.D.539A—High Altitude Controls Lubricants—1 part by weight of D.T.D.577 grease and 2 parts by weight of kerosine—would also be reasonably good. This Norma–Hoffman bomb test provides a means of gauging the likelihood of the development of undue organic acidity—very possibly corrosive—on storage, and it is probable that it will prove to be valuable in further work on protectives, and other products, such as hydraulic fluids and oils, as well as on greases. The method and the results of recent experiments on a number of greases and corrosion inhibitors are discussed later.

Special Features of Temporary Protectives.

From the theoretical standpoint, the success of any protective for a metal surface will depend on its ability to overcome any immediate corrodants

such as finger-prints, other impurities, or hydrobromic acid or other combustion products of fuels, and to form a complete coating as far as possible impermeable to such corrodants as oxygen and water. It would seem preferable for the coating to be, if possible, inert to these, as well as impermeable. In the case of many paints, however, the formation of the protective layer is associated with the oxidation of a drying oil. It is likely that with some soft-film temporary protectives, metallic surfaces are preserved by the protective being sacrificially oxidized, and the layer can be expected to remain protective until the developed acidity is corrosive or until the film breaks and becomes permeable to oxygen and water, etc. In addition to the above considerations, the more inert a film is to other disturbing influences—atmospheric, biological, and mechanical—the more efficient it will be. The type of film chosen, hard or soft, or solid or liquid, will depend on the purpose in view. In general, one forms the impression that solid films are more efficacious than liquid films, being less removable by mechanical disturbance or as a result of temperature changes. It is not always suitable to use solid films, as for instance, in corrosion-inhibiting instrument oils. Mineral oils on their own cannot be expected to be very good corrosion preventives, because they are liquids which dissolve water and oxygen, and oxidize.

From the practical standpoint, in addition to durability, the two main demands of a protective are those of ease of application (by dip or spray) and ease of removal, especially from small interstices. A dye is usually added to a preparation giving a transparent coating to ensure complete distribution of the protective. Usually the weight of the temporary film is well below that of the ordinary aircraft protective, the average film weight of the temporary protective being 0·5 oz/sq. yd. Good adhesion and wetting powers are essential. Lanolin protectives have high wetting powers, and are able to displace water from a surface so that the component need not be carefully dried before being sprayed. A desirable feature in a protective coating is absence of brittleness at low temperatures to avoid flaking and cracking of the film during handling. Since the temporary protectives are often in the form of solutions, consideration has to be given to the questions of fire risks, toxicity of vapours, incidence of dermatitis, etc. A non-tacky film is usually desirable to avoid sticking together of parts which have been treated, and damage to clothing.

Methods of Test.

Exposure Tests.

The durability of a transparent lanolin temporary protective under stores condition in temperate climates is of a high order, although its film weight is low, but in sunlight and open weather the durability is considerably less than that of the ordinary pigmented or opaque coatings. Where a temporary protective is required for stores purposes the correct method of test appears to be to examine and compare it with other protectives under stores conditions. This is usually done together with tests in an open shed, with a roof to shield the specimens from direct sunlight and rain. In addition, for the purpose of obtaining useful comparative data, roof-exposure tests, angle of slope 60°, southerly aspect, and sometimes

marine-exposure tests subjected to the ebb and flow of the tide, are carried out together with laboratory tests. Exposure out of doors, as a test for general information, is useful, even when the protective is not directly intended for such use. Experimental conditions have varied widely.

The first important stage in testing is the preparation of the specimens and test panels; actual treated specimens, if obtainable, are preferable, but often test panels of the materials are used. These panels should not be too small because of edge effects, and in ordinary circumstances should not be less than 2 in $\times$ 6 in, and preferably 4 in $\times$ 6 in or larger. After cleaning and preparing the panels by grit blasting, etc., they should be carefully handled to avoid finger-prints, which cause rusting, and stored in a desiccator or other suitable place until they are ready for the application of the temporary coating. The specimens should be in duplicate or triplicate to avoid idiosyncrasies of the panels. It has been found convenient to register each coated panel with consecutive numbers, each panel being stamped with the number prior to cleaning and preparation. A register is arranged for keeping records of the dates of coating and commencement of the exposure, the material and method of preparation of the panels, observations made from time to time, and the date of the end of the tests, with a brief record of the meteorological conditions over the period.

It is important with exposure tests, in comparing the suitability of coatings, to make frequent observations, especially of the first signs of deterioration; the length of the induction period during which there is little or no visible sign of deterioration is a useful indication of the life of the coating. When once deterioration sets in, the rate appears to increase more or less rapidly, and for this reason the appraising of coatings from their visual appearance after an arbitrary period of time is less helpful than that from a record of their complete history during exposure. Under marine conditions when magnesium and other light alloys are concerned, the visual tests must be supplemented by laboratory tests of the specimens for intercrystalline corrosion, destruction of the chromate or electrolytic coating, etc.

With steel specimens and an opaque coating a portion of the coating is removed after exposure, to see whether rusting has occurred underneath the film.

Weather conditions being so variable and the surface conditions of materials varying with contamination, oxidation, etc., reliable information on the efficacy of a protective is only obtained by tests repeated over and over again, augmented by results of service trials. It has been found essential in all testing and comparing of protectives to include among the specimens panels coated with a standard material about which a good deal is known from the standpoint of weathering and service trials, and to do tests as already stated, in triplicate or at least in duplicate.

In reporting, it is usual to give results in the order: (*a*) better than the standard coating; (*b*) equal to or similar to the standard; and (*c*) worse than the standard panel, the results being arranged in order of merit from best to worst. With temporary coatings which may soften and run during hot weather, it is advisable to note film weights after the exposure, as failure occasioned by thinning of the film may be traced by this means. A photographic record and in some cases photomicrographs up to 10 $\times$ magnification are useful for showing cracking, blistering, crazing, etc., of the film.

Marine tests in which specimens have been exposed to the ebb and flow of the tide were mainly for the testing of protectives, including temporary anti-fouling top coats, for seaplane hulls and floats, but test specimens for other purposes were included in the marine tests for general information. Often, the results were not more severe than on the roof. In the roof testing it was frequently found that there was more severe corrosion on the reverse side than on the side exposed to the sun and rain, so it is necessary to record the condition of both sides of the panel.

Accelerated Tests.

Where relatively quick results are required in the appraising of temporary protectives from the standpoint of durability, it is necessary, particularly when special conditions are being considered, such as those of the tropics, to resort to humidity cabinets and accelerated weathering tests. This subject of accelerated weathering is being intensively studied, and the correct conditions of test have to be worked out for various classes of protectives, and the conditions under which they have to function. An interim report on this subject has recently been issued by the Inter Service Panel for Co-ordination of Research on Paints and Varnishes.* This should be consulted for a complete review of the subject.

It is of interest that in the actual D.T.D. Specifications 121D, 420B, 663, 279B there are no accelerated weathering tests, but these have been used in development work.

In the realm of temporary protectives the most prominent type of accelerated test is that using a humidity cabinet to simulate tropical conditions of high humidity and temperature. In one instance the following cycle of conditions was used :—

First day . .	140° *F* (60° *C*) *and* 80 *per cent R.H. for* 24 *hr*
Each of next 12 *days*	90° *F* (32° *C*) *and* 95 *per cent R.H. for* 8 *hr* 80° *F* (27° *C*) *and saturation with condensation on the specimen for* 16 *hr.*

The complete cycle of thirteen days was repeated for six months.

The film weights of the temporary protectives were determined before the panels were inserted in the cabinet and after the six months' exposure, to check whether any loss by melting and draining occurred. Where packaging with cellulose-film wrappings was made, the tests were repeated with the wrappings. In this work (R.A.E. Chemistry Note No. 909, June 1945) temporary protectives were placed in the following order : D.T.D.279B, C.S.881E, D.T.D.587, D.T.D.121D, D.T.D.663, C.S. 1033A.

The humidity cabinet used at Harefield is of the type described in C.S.2298B. In this specification test the requirement is that the prepared panel should be suspended vertically for 240 hr in a closed chest in which the relative humidity is kept at approximately 100 per cent and the temperature varies between 42° and 48° C, in such a way that continuous condensation of water takes place on the panel. The temperature of the chest should be maintained by electric heaters and regulated by a suitable thermostat. Efficient circulation of the saturated air is effected by a suitable fan.

* Available from Technical Information Bureau, Ministry of Supply.

Another type of humidity cabinet is described in U.S. Specification AN-H-31.

As an example of accelerated weathering, the B.S.987 method used in a comparison by the Chief Chemical Inspector, Ministry of Supply, of U.S. Hard Film Temporary Protectives with C.S.1033D may be quoted. It is described as :—

> " Exposure in an apparatus consisting essentially of a cylindrical container approximately 4 ft in diameter with vertical sides to which test panels are fixed. An uncored carbon arc, enclosed in resistance glass and consuming across the arc between 800 and 950 watts, is suspended eccentrically (approximately 7 to 9 in from the centre) and a fine water spray is situated centrally so as to direct a spray of water on the face of the panels in front of it. The container is revolved slowly, three revolutions per hour, and the relative positions of the spray and arc are such that a panel passing from the spray to the point nearest the arc, traverses one quarter of the circumference of the container."

In the present apparatus at Harefield, modified for development work and not so far used for temporary protectives, the cylinder is 4 ft in diameter, rotating once in 3 hr. The 2000-watt D.C. uncored carbon arc is behind " Hysil " and is 8 in eccentric towards the drying portion. For three quarters of the rotation the plates are sprayed with distilled water, and are exposed to the lamp the whole time.

The methods used in the recent work on the question of whether both D.T.D.663 and C.S.1033D need be retained for inter-service use were as follows :—

Armament Research Est., Woolwich (using brass, duralumin, magnesium, and steel)—

(*a*) Outdoor exposure at Woolwich, the specimens being inclined at an angle of 45° to the horizontal and facing south.

(*b*) Salt Spray testing in accordance with B.S.1391.

(*c*) Exposure to hot damp conditions such that the test surfaces periodically received condensation of small droplets of water at 40° C.

A.I.D. Harefield (Steel, Aluminium (1) chromated D.T.D.915 and (2) degreased, Dural (1) chromated, D.T.D.915 (2) degreased, Magnesium (1) chromated, D.T.D.911 (2) degreased).

(*a*) Natural weathering for six weeks.

(*b*) Humidity cabinet for four weeks.

Mechanical Tests.

Several separate tests are usually required for measuring film properties and hardness, time of drying, tackiness, the development of brittleness at low temperatures, and ease of removal, etc. The usual bend test around a mandrel and scratch-hardness test with observations on the appearance of the scratch afford useful information on the hardness and development of brittleness at lower temperatures. The measurement of tackiness is a difficult subject, and usually an instrument affords less information than just handling. Application of the warmth of the fingers and slight

pressure for a few moments usually indicate whether the film is tacky or not.

In the recent work at Harefield on comparison of D.T.D.663 and C.S.1033D, the following tests were also carried out :—

(*a*) Jet Clearance Tests. Time taken to remove $\frac{1}{8}$-in diameter $\times \frac{1}{8}$ in long plug of preservative by immersion in white spirit.

(*b*) Appearance of protective after heating for 2 hr at 60° C (Al).

(*c*) Appearance of protective after cooling for 2 hr at −40° C and then bending—without opening refrigerator door—through 180° round a $\frac{3}{8}$-in diameter mandrel (Al).

(*d*) Impact testing with $\frac{3}{4}$-in steel ball (16 in lb) after cooling 48 hr—dried film at −40° C for 3 hr ($\frac{1}{2}$-in plate, mild steel).

Special Tests of Engine Corrosion Inhibitors.

The current engine corrosion inhibitors were mentioned earlier. In the specifications for these there are special tests to ensure that the materials are capable of protecting steel from corrosion under the severe conditions concerned, and that aluminium and copper will not be corroded. For D.T.D.587 and D.T.D.698 the test methods are the same, except that the latter has previously to be diluted with 15 per cent by volume of lead-free petroleum spirit.

The anti-corrosion test with steel is designed to test the corrosion-inhibiting effect in presence of hydrobromic acid, which is present in the combustion products of leaded fuels. Briefly, the test is as follows :—

A solution of hydrobromic acid in kerosine is prepared, to have a concentration of 0·20–0·25 g HBr per 100 ml. A sand-blasted S.30 steel strip, specially prepared as detailed in the specification, and weighed to the nearest 0·1 mg, is immersed in the kerosine solution of hydrobromic acid and then removed and allowed to remain suspended from a glass hook for 15 min. It is then immediately immersed for 5 sec in the material under test, removed and drained for 5 sec, and this process, *i.e.*, of dipping and draining, repeated until it has been done in all six times. The panel is allowed to drain for 1 hr, after which any excess of oil is removed from the bottom edge by means of a filter-paper. The panel is then suspended in a closed vessel of approximately 5 litres capacity over saturated zinc sulphate solution, so that the bottom edge of the plate is 1 in above the surface of the liquid. After 24 hr at 20° ± 2° C the plate is removed, washed in two successive 100-ml portions of hot benzene, dried at 100° C for 15 min, cooled in a desiccator, and weighed. The benzene washings, containing any traces of rust removed from the panel, are poured through a Whatman No. 41 ashless filter-paper, which is then ashed and the weight added to the final weight of the panel. This test is made in quadruplicate, and the increase in weight of any panel is required to be not more than 1 mg from the average of the four. It is required that the panels shall show not more than uniform staining and that the average change in weight shall be not greater than 5 mg. By the use of this test it is possible to find the number of safe times of use of storage oil in the lubricating-oil system of a stored aircraft.

In the tests for determination of freedom from substances corrosive to non-ferrous metals, electrolytic copper foil and aluminium foil are used. Panels 3 in × 1 in are prepared as in I.P.64/42, washed with pure benzene, dried at 100° C, cooled in a desiccator, and weighed. The weighed panels are completely immersed in the material under test, in separate clean tubes or bottles, which are then placed, uncorked, in an air oven at 100° C for 24 hr. After cooling, the panels are removed, washed with pure benzene, dried at 100° C, cooled in a desiccator, and weighed. It is required that the metal panels shall show not more than slight uniform staining, and that any change in weight shall not exceed 2 mg.

In the draft specification D.T.D.791 (March 1948), for the wax-thickened engine corrosion inhibitor designed for use in tropical climates, the test for freedom from corrosive substances is somewhat similar to that in the previous paragraph. Strips (3 in × $\frac{1}{2}$ in) of aluminium foil, electrolytic copper foil and polished mild steel, similarly prepared, are placed in separate conical flasks, and 150 ml of the material added to each. The flasks are heated for 24 hr on a boiling-water bath, and at the end of this period the residues are poured off, the strips washed with hot A.R. benzene, and examined for signs of discoloration or corrosion. It is required that they shall show no signs of corrosion, and not more than slight uniform staining.

In further development work on D.T.D.791, tests were done with various materials on 4 in × 2 in × $\frac{1}{16}$ in B.S.84 steel panels with a standard finish produced by No. " O " emery cloth. The panels were dipped in a solution of hydrobromic acid in kerosine as in the D.T.D.587 specification test, but sprayed with the material under test in a cylindrical vessel of similar dimensions to an engine cylinder, through a central hole in the lid. Each panel was then suspended by one corner, using a stainless-steel hook, in an oven at 60° C, and after 18 hr surplus droplets were removed with clean filter-paper, and the panels weighed. After a further draining period at the same temperature the panels were again weighed. The plates were then inserted in a humidity cabinet at 140° F—in accordance with U.S. Army–Navy specification AN-H-31—and examined at intervals. The time at which rusting was first observed on each panel was noted. It was found that the times of failure of the two faces of any panel did not differ greatly, and the mean value of the two was used as the result. This work established that D.T.D.791 was a very efficacious corrosion inhibitor, the plates being in excellent condition after 42 days in the cabinet.

Other Laboratory Tests.

There are some other tests of a general nature which are included in various specifications as applicable. Examples are as follows :—

Acidity or alkalinity (D.T.D.561, 55, 122B, 539A, 804)
pH of distilled water extract (D.T.D.561, 555)
Saponification No. (D.T.D.122B, 804)
Impurities such as chlorides and sulphates (D.T.D.555, 804)
Flash point (D.T.D.561, 539A)
Corrosive sulphur (D.T.D.539A)
Moisture content (D.T.D.122B)
Corrosion of copper at 100° C (D.T.D.561, D.T.D.577)
Protective effect on steel immersed in synthetic seawater (D.T.D.561)

Oxidation Stability Tests.

The Norma–Hoffmann oxidation test is well established in modern grease specifications. Details are most readily available in A.S.T.M. D.942–47T and in such specifications as AN-G-3a, D.T.D.577, AN-G-5a, AN-G-15a, AN-G-25. The bomb in D.T.577 is slightly different in internal height, 3·34 in as compared with 3·3125 in of the U.S.A. bomb, and the temperature conditions are slightly different, the U.S. specifications requiring 99° C with an overall variation of not more than 0·5° C (or 210° F and total variation not exceeding 1° F) as compared with 100° C ± 0·25° C. A.S.T.M. D.942–47T and VV-L-791d 345·3 quote twice these temperature tolerances, *i.e.*, 210° F ± 1·0° F.

Briefly, 20 ± 0·1 g of grease, distributed equally and with plane surfaces in five glass dishes, is treated with oxygen under pressure—adjusted initially to 110 p.s.i. at reaction temperature of 100° C ± 0·25° C (D.T.D.577). Observations are made of pressure drop and time, and in any investigation work initial and final total acidities are also determined. This test is under investigation by the General Tests of Greases Panel of the Institute of Petroleum prior to publication in " Standard Methods." The usual specification requirement for a grease is that there shall not be more than 5 lb pressure drop in 100 hr : for AN-G-5a the requirements are slightly different—50 lb maximum pressure drop in 500 hr at 99° C on qualification, and 10 lb maximum drop in 100 hr in inspection tests.

In the revised Norma–Hoffmann test, dated January 1946, a relation is stated between induction period and shelf life of ball bearings with steel retainers, *i.e.*,

Induction period, hr.	Shelf life.
50	Less than 1 year
150	2–3 years
500	More than 4 years

Following investigations on corroded bearings, experiments were initiated in the A.I.D. Laboratories at Harefield on a variety of materials, including a number of temporary corrosion preventives, and this work is being continued. For liquids, 50 ml was used in a single glass container. Waxes were shredded—these melted in the bomb. The results on pressure drop versus time are shown graphically in Figs. 1 and 2 (*Note*—In Fig. 2 the time scale is four times that of Fig. 1), and in Table I the results for total acidity are given, together with notes on the effects on steel balls, where these were included.

It is felt that the results of such experiments indicate what may eventually happen if oxidizable materials are left in contact with corrodible surfaces for overlong periods. It is possible to make the following observations :—

(i) A lime-base grease which had given trouble in corrosion of bearings during storage gave rapid breakdown (6). This was not accelerated by steel balls, but the balls were badly etched where immersed in the grease.

(ii) With a stable grease these effects do not take place (3 and 5).

(iii) Lanolin breaks down rapidly. This suggests that lanolin is not really reliable for long-period work. When steel balls are present they do not accelerate the breakdown, but rust (13 and 14). This

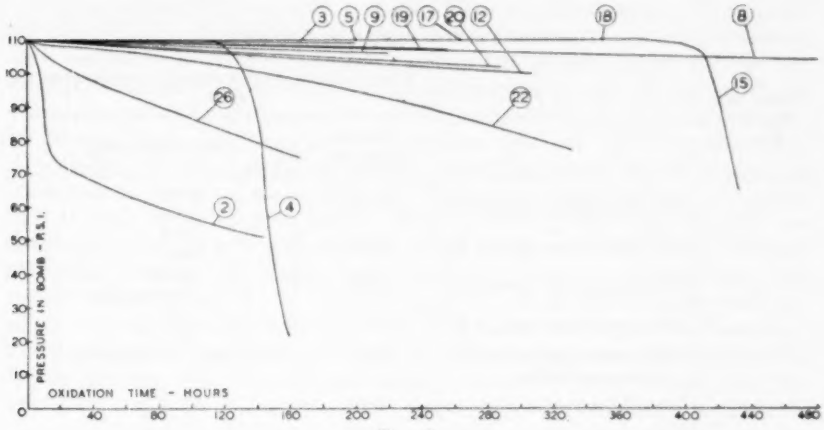

FIG. 1.

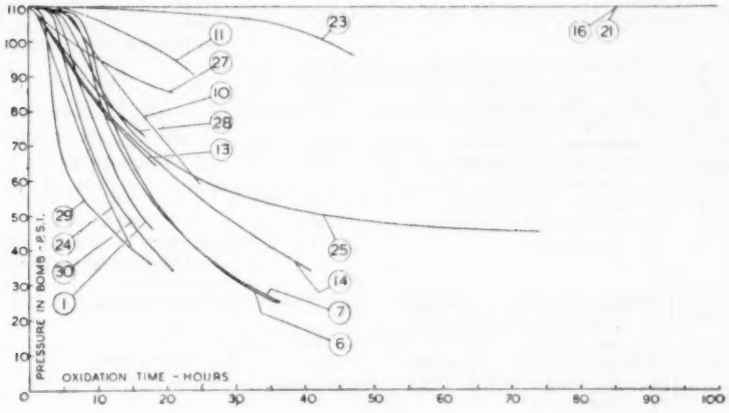

FIG. 2.

rusting effect is probably associated with the water content of the lanolin.

(iv) Certain materials are very stable—D.T.D.791 and the microcrystalline petroleum wax used in it (17 and 18), D.T.D.783 (19), mineral jelly (8 and 9), D.T.D.539A (15 and 16)—though (15) shows eventual breakdown. A kerosine gave a pressure drop of only 5 lb, in 645 hr. The stability of the microcrystalline petroleum wax indicates that it may find further uses as a thickening agent.

(v) Certain other materials oxidize very quickly—Beeswax (C.S.2177), a sample of C.S.2298B (this sample did not pass the humidity cabinet test), D.T.D.663, and various proprietary corrosion preventives.

(vi) Intermediate stability is shown by a specimen of lanolized mineral oil (22), mineral jelly–beeswax (C.S.2296) (12), AN-G-5a grease (20).

TABLE I.

Total Acidities before and after Oxidation.

Index no., Fig. 1 or Fig. 2.		Total acidity, as per cent by weight oleic acid.	
		Before oxidation.	After oxidation.
1	I.P. correlation grease A	0·14	{6·4 6·5
2	I.P. correlation grease B	0·13	{3·6 6·9
3	I.P. correlation grease C	0·05	{0·03 Negligible
4	I.P. correlation grease D	0·3	{9·9 5·7
5	I.P. correlation grease C, with steel balls	0·05	Steel balls unchanged.
6	Lime-base grease	0·26	{5·8 10·6
7	Lime-base grease, with steel balls	0·26	9·7 Majority of balls badly etched, with a matt appearance on the portion of the ball immersed in the grease.
8	Mineral jelly, D.T.D.55	0·21	0·69
9	Used mineral jelly	0·24	0·12
10	50% Mineral jelly, 50% lime-base grease	0·24	6·8
11	Beeswax, C.S.2177	9·3	10·8
12	Mineral jelly–beeswax preservative, C.S.2296	0·12	Indistinct
13	Lanolin, D.T.D.122B	0·89	5·3
14	Lanolin, D.T.D.122B and steel balls	0·89	9·96 Balls dark brown in colour and badly corroded—rusty appearance.
15	High-altitude controls lubricant, D.T.D.539A Sample 1	Nil	Not determined.
16	High-altitude controls lubricant, D.T.D.539A Sample 2	Not determined.	Not determined.
17	Wax-thickened engine-cylinder protective, D.T.D.791	Not determined.	0·26
18	Microcrystalline petroleum wax—as used in D.T.D.791	0·07	0·07
19	General-purpose aircraft grease, AN-G-15	0·07	1·15
20	High-temperature grease, AN-G-5a	Not determined.	Not determined.
21	High - melting - point grease, D.T.D.783	Nil	Nil
22	Lanolized mineral oil	0·09	3·15
23	I.P. correlation grease E	$<0·08$	Max of 2·3 in dish 2, without bleeding of oxygen.
24	Preservative for metal components containing rubber, C.S.2298B	6·8	5 hrs.—11·3 15 hrs.—21·6
25	Corrosion inhibitor 1	1·43	8·3
26	Corrosion inhibitor 2	1·50	4·30
27	Lanolin–resin protective, D.T.D.663	0·8	1·2
28	Corrosion inhibitor 3	0·17	1·7
29	Corrosion inhibitor 4	0·87	4·34
30	Corrosion inhibitor 5	0·33	3·25

A good deal of further work could be done on this subject. It has not yet been shown, for instance, that rapid oxidation corresponds necessarily with corrosive acidity. The effects of various metals could well be investigated much further—this topic is in progress in the U.S.A., and the effect of a phosphor-bronze accelerator is mentioned in the revised Norma–Hoffmann test. In the bomb oxidation test of U.S. Specification AN-C-124a (16 Oct. 1946)-Compound ; Soft-Film Corrosion-Preventive, a brass disc is placed in each of the five dishes, and the pressure drop must not exceed 10 lb in 200 hours. The nature of the acids formed on oxidation, both on ordinary storage and in oxygen bombs, would be most interesting topics. Although much remains to be done, it is felt that the results obtained will be of current interest. It is appreciated that the effects of oxidation may be complex and may include development of acidity, disintegration of coatings or the beneficial effect obtained with drying oils. Unless the last effect is being aimed at, there seems to be a good case for selecting corrosion inhibitors with the maximum oxidation resistance. There is increasing evidence of the correlation of bomb oxidation tests and storage tests with grease-lubricated mechanisms, for example, in the work of H. Gisser and F. L. Meshkov, A.S.T.M. Bulletin No. 140, 1946, pp. 57–62.

ACKNOWLEDGMENTS.

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AMERICAN METHODS OF TESTING TEMPORARY CORROSION PREVENTIVES.

By C. F. McCUE * (Associate Member) and E. R. BLANE † (Fellow).

SUMMARY.

A critical review is presented of the more important methods used in America, both in the laboratory and in the field for assessing the degree of protection afforded by temporary corrosion preventives. The significance of results obtained with some of the tests is discussed, and work is quoted which demonstrates that, whereas no single test can be relied upon always to correlate well with practice, a better assessment can sometimes be obtained by considering the results of two or three different tests in conjunction.

INTRODUCTION.

THE purpose of this paper is to summarize critically the methods used in America for assessing the performance of temporary corrosion preventives. No attempt is made to deal with all the various aspects of testing these materials; the scope is restricted to what might be termed "rusting" tests. These fall into two classes: (1) Accelerated laboratory tests; and

* Anglo-American Oil Co. Ltd.
† Vacuum Oil Co. Ltd.

(2) Simulated field tests, and they are considered under these headings. It should be noted here that, contrary to British practice, temporary protectives are quite widely used in the U.S.A. for the preservation of metals exposed to outdoor conditions; some of the methods of test are therefore designed to cater for such usage.

Accelerated Laboratory Tests.

Humidity Cabinet Tests.

Several different designs of humidity cabinet are in use in the U.S.A., and the modes of operation are even more numerous. So far, the A.S.T.M. have not felt justified in standardizing either the design or operational technique, and probably the nearest approach to a "standard" cabinet is that described in Army–Navy–Aeronautical Specification AN–H–31. This cabinet (Fig. 1) consists of a thermally insulated brass tank measuring about 30 in cube and fitted with a lid consisting of two sheets of linen separated by a 1-in air-space. The tank contains about 8 in of water, and air is bubbled through this at a rate of 8 linear feet per hour (*i.e.*, about 44 cu. ft/hr or roughly three changes per hour). Specimens, usually consisting of sand-blasted mild-steel panels, are suspended from a rotating stage located near the top of the cabinet; any water condensing on these specimens falls into a drip-tray, and so does not contaminate the rest of the water in the tank. The temperature in the cabinet is controlled by means of heaters immersed in the water, and tests are usually conducted at an air temperature of either 100° or 120° F.

Another humidity cabinet to which reference is made in some U.S. Services specifications is that known as the Rock Island Arsenal cabinet (Fig. 2). This operates at a temperature of 100° ± 2° F and a relative humidity of 95 to 100 per cent, and air is passed through at such a rate as to give 1 to 1½ complete changes every hour. Specimens which usually consist of polished or sand-blasted 3 × 2-in panels are held in wooden racks.

Most operators seem to be agreed that, although these cabinets are very useful for manufacturing control purposes, results obtained with them do not correlate well with practice; in fact, it is very difficult to obtain reproducibility between what appear to be identical cabinets operating under identical conditions. Comparative tests carried out at Rock Island Arsenal laboratory [1] indicate that the reproducibility obtainable with the AN–H–31 type cabinet is better than with the Rock Island Arsenal cabinet.

Perhaps the most important difference between these cabinets and the British "C.C.I." cabinet is that in the American models the temperature is kept constant, whereas in the British pattern the temperature is cycled between 42° and 48° C. In this respect the "C.C.I." cabinet might be claimed to simulate normal exposure conditions more closely than the American cabinets, since in use the coating will normally be subjected to variations in both temperature and humidity. Some American operators attempt to overcome this objection by removing the specimens from the cabinet for 5 hr each day and exposing them to ultra-violet light; this is claimed to improve correlation with performance in service.

Some of the large steel companies in the U.S.A. employ what is known as a humidity cabinet–cycle test. This involves fastening coated steel test

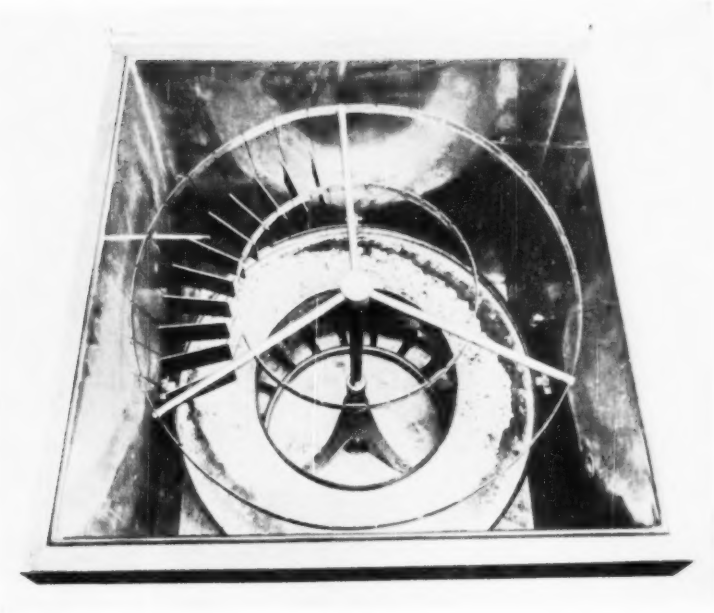

FIG. 1.

AN-H-31-TYPE HUMIDITY CABINET—INTERIOR VIEW.

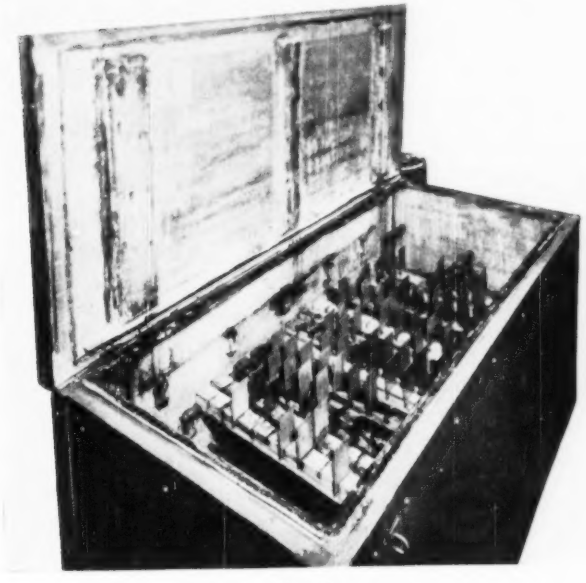

FIG. 2.

ROCK ISLAND ARSENAL HUMIDITY CABINET.

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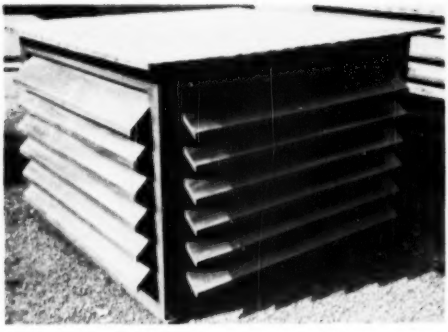

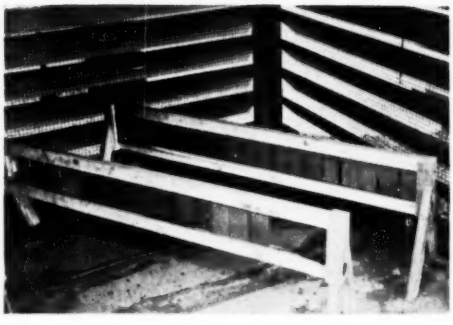

FIG. 3.

SHED EXPOSURE TEST. (*Top*) EXTERIOR AND (*right*) INTERIOR.

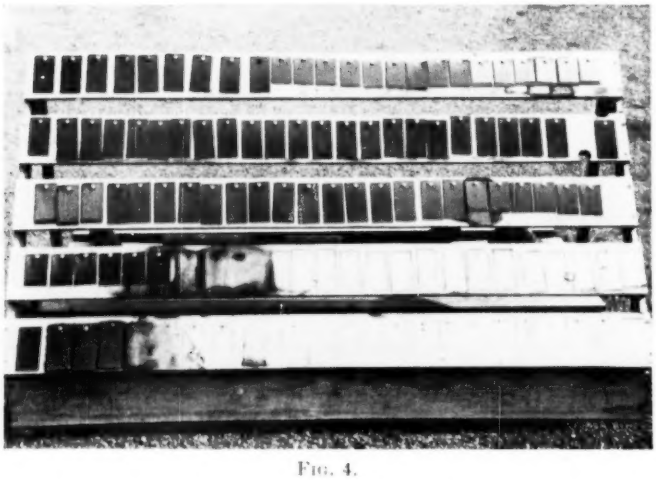

FIG. 4.

OUTDOOR EXPOSURE RACK

panels flat against the side of a small metal tank filled with ice-water, and placing this tank in a cabinet through which relatively warm air at 100 per cent relative humidity is circulated. Condensation occurs, and these conditions are maintained for 5 hr, after which the ice-water is drained and warm, dry air circulated through the cabinet for the remaining 19 hr of the cycle. The panels are inspected for signs of rusting after each cycle. Better correlation with sheltered outdoor exposure is claimed for this test than for the AN–H–31 cabinet. This might be expected, because in the latter test a heavy emulsion is often formed which affords a long-lasting protective coating seldom obtained in service. When this occurs the coating may protect longer in the accelerated test than in actual exposure. In the cycle test the emulsion is broken during the 19-hr drying period, and failure of the protective often occurs in a relatively short time.

A fault common to all humidity cabinet tests (and indeed to practically all accelerated rusting tests) is that the duration of the test is so short that it takes very little account of the ageing characteristics of the coating. Ageing may play an important part, for good or ill, in the performance of the protective.

Salt-spray Tests.

A salt-spray test for the evaluation of electro-deposited metallic coatings, tentatively standardized by the A.S.T.M. under designation B117–44T, was adopted during the war as Emergency Method ES–3 for the evaluation of organic protective coatings, and it was widely included in Army and Army–Navy Aeronautical specifications for products used for outdoor exposure. In this test specimens are exposed to a fog of particles of a 20 per cent salt solution at 95° F; no spray impinges directly on the specimens. No procedure has been given by the A.S.T.M. for the preparation of test panels, this and the interpretation of the results obtained being left to mutual agreement of those using this test. It is stated in an appendix to the latest version of the method that there is seldom a direct relation between resistance to salt spray and to corrosion in other media. As with the humidity cabinet, the salt-spray test gives no indication of the ageing qualities of a film. For this reason it is of use in predicting short-term life of rust preventives under outdoor conditions but of less significance where long-term exposure is of interest, since it does not predict the development of flaws in the coating caused by exposure to sunlight, rain, and temperature changes.

The National Paint, Varnish, and Lacquer Association Inc.[2] have studied the variables involved in the operation of salt-spray tests and have found that the following must be carefully controlled if reproducible results are to be obtained: purity of salt, concentration of salt solution, atomization pressure and type of orifice, salt-chamber temperature, use of clean air of high humidity, pH of salt solution. With regard to the temperature of the chamber they are emphatic that this must be maintained by locating the entire apparatus in a thermostatically controlled room or cabinet and not by the use of an immersion heater.

Weathering Tests.

Several types of accelerated weathering apparatus are in use in the U.S.A. for the assessment of the more resistant protectives, particularly those of

the hard-drying variety; probably the most widely used machines are the Atlas weatherometer and the National Carbon Co's Model X–1A. Generally speaking the test is intended to simulate conditions which might be encountered in outdoor unsheltered storage; exposure to ultra-violet light, the washing action of a water spray, abrupt changes in temperature, and high humidity are all available, and may be used in combination or cycled as required. Most experience with this test has been obtained in the assessment of paints and varnishes, and it forms part of many U.S. Government specifications for these products. In a critical review of such usage, G. G. Sward [3] has recommended that assessment of results should be limited to the evaluation of colour change, gloss retention, and chalking tendencies only, and should *not* embrace other properties such as checking, peeling, or rusting. However, there is no doubt that, for the testing of temporary protectives intended for use under severe conditions of exposure, accelerated weathering does offer some advantages over the humidity cabinet or salt-spray type of test.

Miscellaneous Tests.

In this section such tests as seawater-immersion, water-spray, water-drip, and static-water-drop methods will be briefly mentioned. None of these methods appears to be standardized, and some are only in the experimental stage; however, the following details relate to tests that are actually in use in various laboratories in the U.S.A., and they may be regarded as typical.

Seawater-immersion Test. This is a simple test designed to measure the protection afforded by the coating when immersed in seawater. Coated test panels are merely placed in synthetic seawater and inspected daily for signs of rusting. There seems to be very little information available on the correlation of this test with practice, but it is included in several U.S. Services specifications.

Water-spray Test. Coated panels are placed at an angle of 30° to the horizontal, and tap-water maintained at 75° to 80° F is " rained " on them from a height of 2 ft. A cycle of 3 min on, 3 min off, is repeated until the first signs of corrosion appear. This test is, of course, intended to simulate direct exposure to the elements, and would seem to be a desirable addition to humidity cabinet tests when dealing with products intended for outdoor use. It is interesting to note that some coatings which perform very well under the water spray fail in the humidity cabinet and vice versa.

Water-drip Test. In this test [4] drops of dilute (0·05 per cent) sodium chloride solution are allowed to run down the inclined face of the coated panels. Results are obtained in a comparatively short time, poor coatings showing signs of failure in less than 10 min. Moreover, correlation with shed-storage performance seems to be quite good, as will be shown later.

Static Water Drop. Considerable interest has recently been shown in the U.S.A., as elsewhere, in the extremely simple type of test whereby one or more drops of water are maintained on the surface of the coated panel and observed at specified intervals.[5,6] Much of the work is still in the exploratory stage, and very little information has been published; however, as will be shown later (Table II), at least one such test [6] (in which 10 drops of 0·05N salt solution are placed on the specimen and inspected hourly) has shown some promise as a means of assessing the performance of a protective under

shed-storage conditions. It remains to be seen, however, whether such simple techniques will ever displace the more elaborate tests now employed.

Simulated Field Tests.

All the tests so far considered are accelerated tests, and suffer from the disadvantage common to such tests, namely, that in order to obtain a result in a reasonably short time a certain amount of artificiality has been introduced, with the result that the conditions of the test are not those normally found in service. Results obtained by such tests can be considered significant only to the extent that they correlate with actual practice. For this reason simulated field tests are widely used as a check on laboratory results and as the ultimate criterion of the performance of a protective. Broadly speaking these field tests are of two types.

Shed-exposure tests, in which the coated panels are hung in a shed or louvred cabinet (Fig. 3) so that they are subject to atmospheric conditions of temperature and humidity without being exposed to direct rain or sun. Sometimes a pan of water or salt solution is placed in the exposure cabinet to keep the atmosphere humid.

Outdoor-exposure tests, in which the specimens are directly exposed to the elements. Panels may be hung vertically or supported at an angle; when the effect of sunlight is of interest a rack at 45° facing south is commonly used (Fig. 4).

A big disadvantage of these tests is the fact that the conditions cannot be controlled, since they are entirely dependent on the prevailing weather. In this respect workers in the U.S.A. are more fortunate than those in the U.K. because by suitable choice of location and season they can be reasonably certain of obtaining the desired climatic conditions. Furthermore, they have a wider range of climate available—from sub-tropical to arctic.

There is in the U.S.A. a number of independent testing stations where exposure trials may be conducted. One of the best-known of these stations is the South Florida Test Service of Miami, which offers testing facilities under a variety of conditions, such as inland or coastal exposure, undercover storage, etc. It is claimed that results of tests carried out here closely parallel the ultimate failures found in more northerly latitudes but are accelerated many times due to the constancy and high values of such climatological conditions as humidity, temperature, etc. The following details of a test now in progress at this station may be of interest.

Twenty-eight different products are being assessed, and panels coated with these are subjected to five types of exposure :—

(1) Directly exposed to the elements at an inland location—panels placed at 45 deg to the horizontal facing south.

(2) Directly exposed to the elements in a beach-front salt atmosphere —panels placed at 45 deg to the horizontal facing south.

(3) Directly exposed to the elements at an inland location—panels hung vertically with prepared surface facing south.

(4) Directly exposed to atmospheric changes of temperature and humidity, but protected from rain and direct sunlight—panels hung vertically.

(5) Panels hung indoors in a vertical position.

In this test the following data are being recorded for each product: Number and type of panels, coating temperature, rate of withdrawal, draining time, weight or thickness of coat, conditioning time, type of exposure, type of inspection, physical properties of the product, and details of weather, including hours of sunshine, maximum and minimum temperature, rainfall, etc.

Solid products were applied either by dipping at an elevated temperature (160°–185° F) or by spreading with a spatula. For products diluted with solvent dipping was carried out at room temperature. Rate of withdrawal

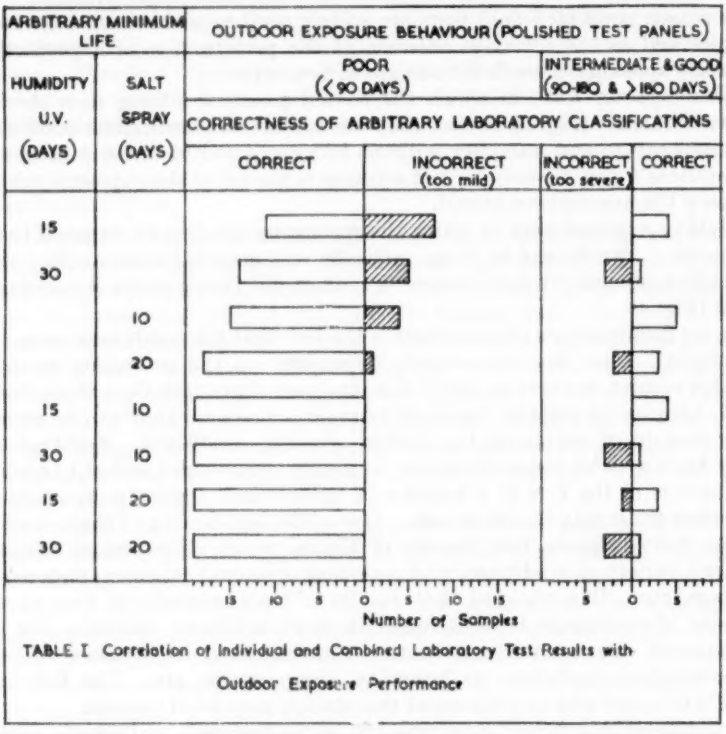

TABLE I Correlation of Individual and Combined Laboratory Test Results with Outdoor Exposure Performance

is important, as this factor controls the weight of film retained on the panel. All panels were allowed to age for a definite period usually 24 hr at room temperature.

It is obvious that specimens for such tests must be carefully prepared and handled. A general practice is to use 2 × 3 in or larger panels cut from cold-rolled steel. These test panels may be either sand-blasted or polished with fine emery cloth. In certain industries the actual articles manufactured are used.

After the surface is prepared, the panels are cleaned with a petroleum solvent and finally washed in boiling methanol to remove finger-print residues. Surfaces prepared in this manner are highly sensitive to corro-

sion, and must be stored in a desiccator or otherwise protected until they are to be used. They must be handled with clean tongs or suspension hooks.

Significance of Results.

Although there is very little precise information available on the significance of results obtained by the various tests described above, most workers are agreed that no single laboratory test can be relied upon always to yield results which correlate with the performance of the coating in practice. Obviously the test should, so far as possible, simulate the conditions under which the protective will be used, but, generally speaking, these are not

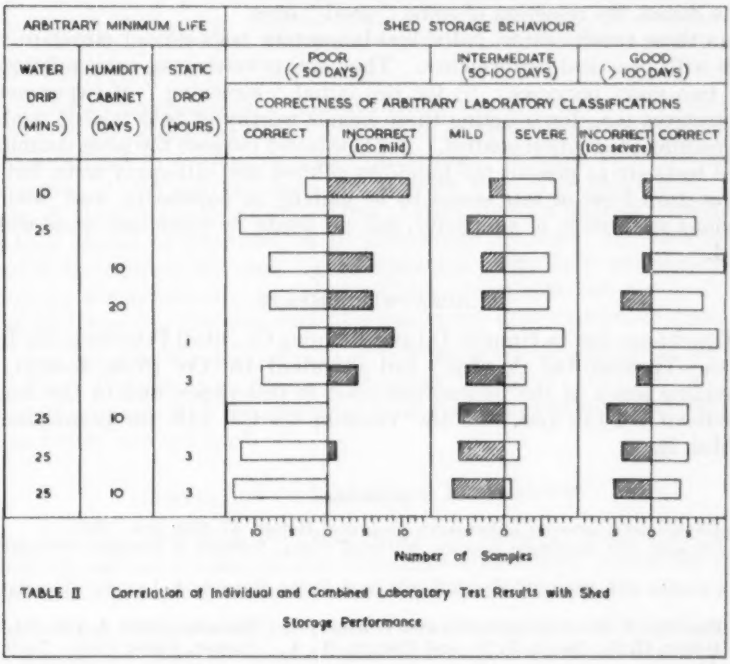

TABLE II Correlation of Individual and Combined Laboratory Test Results with Shed Storage Performance

known and may vary over a wide range. For this reason many specifications require the protective to pass more than one type of test (*e.g.*, humidity cabinet and salt-spray tests). The fact that better correlation with simulated exposure tests is obtained by combining the results of two or three different laboratory tests is well illustrated by Table I, which is taken from a paper by Walters and Larsen.[6] This table shows that a humidity cabinet U-V light life (to incipient corrosion) of 15 days correctly rates four " intermediate " or " good " protectives, but also passes eight out of nineteen " poor " materials; similarly a salt spray life of 10 days allows four of these " poor " materials to pass. Increasing the duration of either of these tests helps to weed out more of the " poor " protectives, but at the same time fails some of the " good " ones. By combining the two requirements,

however (*i.e.*, a humidity cabinet U-V light life of 15 days *plus* a salt spray life of 10 days), all the " poor " materials are failed, and all the " intermediate " or " good " ones are passed. It should be pointed out here that the rating of " good " or " bad " is purely an arbitrary one based in this case on the behaviour of the coating under conditions of outdoor exposure. Table II, taken from the same paper, shows the correlation between shed exposure and three laboratory tests (water drip, humidity cabinet, and static drop). The water drip life of 25 min affords the best individual measure (twelve out of fourteen " poor," and six out of eleven " good " materials correctly rated). Simultaneous consideration with the humidity cabinet test (criterion >10 days), or the static drop test (>3 hr), or both, improves the identification of " poor " materials, but at the same time causes the rejection of some " good " ones.

As these results show, individual laboratory tests do not correlate very well with practical performance. They are, nevertheless, extremely useful for two main purposes: (i) for the initial " screening " of experimental protectives (*i.e.*, for selecting those blends worthy of field trials); and (ii) for routine production control. For this latter purpose the most commonly used tests are at present the humidity cabinet and salt-spray tests, but the water-drop type of test seems to be gaining in popularity, and, with its obvious advantage of simplicity, will no doubt be more and more widely used.

ACKNOWLEDGMENTS.

Thanks are due to Humble Oil and Refining Co., Shell Petroleum Co. Ltd., Socony-Vacuum Oil Co. Inc., and Standard Oil Co. (New Jersey), for providing much of the information used in this paper, and to the Anglo-American Oil Co. Ltd. and the Vacuum Oil Co. Ltd. for permission to publish it.

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PERFORMANCE TESTS, OTHER THAN CORROSION TESTS, ON TEMPORARY CORROSION PREVENTIVES.

By H. Hollis.*

Summary.

Brief details of the methods of test currently used in the performance testing of temporary corrosion preventives are discussed. Tests used for the evaluation of protective properties are not dealt with as they are fully covered in other papers. For full details of test methods the specifications or Institute of Petroleum Methods referred to in the text should be consulted.

The object of this paper is to indicate briefly the properties which can be expected in a temporary corrosion preventive, and the types of test employed by the chemist in evaluating these properties. It must be appreciated that many of the existing tests found their way into specifications at extremely short notice during the stress of war; it is not claimed, therefore, that they cannot be improved, or are necessarily the best. If constructive criticism is forthcoming, and by co-operative effort new and improved techniques are developed, the object will have been achieved.

Before discussing the tests currently employed, it is essential to state :—

(*a*) what is, for the purposes of this paper, to be understood by the term "Temporary corrosion preventives"; and

(*b*) what are the broad classes of temporary corrosion preventives, and how they are used.

Definitions of Corrosion Preventives.

The following definition of a temporary corrosion preventive has been tentatively agreed by the British Standards Institution Committee concerned with the revision of Section 3 of the Packaging Code.

Temporary Corrosion Preventives *are corrosion preventives which can be readily removed from the metal surfaces by wiping, or by the cold application of common petroleum solvents, or, in particular cases, by stripping, or by allowing the material to evaporate.*

General Types of Temporary Corrosion Preventives.

There are five main classes of material commonly used which for ease of reference can be classified as follows :—

Class A. *Oils.*
Class B. *Soft, thin, non-drying films deposited from solvent solution.*
Class C. *Hard, thin, films deposited from solvent solution.*
Class D. *Thick greasy films.*
Class E. *Strippable coatings, thin or thick.*

* Ministry of Supply.

The properties to be expected in any of these materials are :—

(1) The ability to protect the surface to which it is applied from corrosive attack due to high humidity or condensation from the atmosphere.

(2) Freedom from any corrosive action on any of the metals with which it comes into contact.

(3) Ease of removability when the preserved article is taken into use.

(4) Suitability for application, taking into account health and fire hazards.

(5) Film properties which are compatible with any subsequent wrapping or packing which may be given to the preserved article.

(6) Keeping properties in the unopened container.

The performance tests which have been developed or employed for the testing of temporary corrosion preventives have been designed to provide as much information as possible on all the above properties. They naturally vary, however, from class to class, due to the different natures of the materials concerned. Certain tests are, however, basically the same regardless of the type of preservative, and it is easier to deal with these "common" tests first, and then go on to consider the specialized tests peculiar to each class of material.

Tests Common to all Temporary Corrosion Preventives.

Freedom from Corrosive Action.

When a temporary corrosion preventive is first developed it is difficult to envisage the extent to which it may be ultimately employed. It is as well therefore to ensure that it will not be corrosive to a wide range of metals or alloys. In this connexion it must always be remembered that, although a material may not be corrosive to either of two different metals, it may be fatally corrosive to one of those metals when the two are in contact, due to the potential set up when dissimilar metals are in electrical contact. It is, therefore, customary to test the metals in couples, and typical metallic couples which should cover all normal requirements are as follows :—

Magnesium alloy and brass;
Zinc-base alloy and brass;
Mild steel and aluminium alloy;
Mild steel and brass.

If it is known that the preservative is required for some special assembly involving metals or alloys not falling in any of the above groups (*e.g.*, silver–lead-bearing metals, cadmium plating, etc.) it may be desirable to check up on the metallic couple likely to be encountered in practice, but for all normal purposes the above couples should suffice. A detailed method of test is to be found in the Australian Specification SAA/INT/61, in which metallic couples of dissimilar metals are immersed in the protective for a specified time and are then examined for corrosive attack.

Ease of Removability.

This property is most important, and should never be lost sight of; by definition it is the one property which differentiates between the permanent protective such as a paint or varnish and the temporary protective. The ease of removability will, of course, vary according to the type of preserva-

tive, *e.g.*, a strippable type must remain strippable, a solvent-deposited type should be readily removable by means of a rag soaked in kerosine or some similar readily obtainable solvent, etc. No special technique has been evolved for testing this property, nor would it appear to be necessary, and what is required is a straightforward practical trial. It is as well to remember, however, that some types of material undergo chemical and physical change due to oxidation, polymerization, etc., for many months after they are applied, and, as a result, a preservative which is still readily removable one month after application, may become exceedingly difficult to remove after a year's natural ageing. It is as well therefore to test the preservative for ease of removal after a considerable period of natural ageing. A knowledge of the detailed composition may, of course, render this procedure unnecessary.

Keeping Qualities in the Container.

Here again no precise laboratory methods have been worked out, and provided time permits, by far the safest procedure it to set aside a filled container of the preservative for the requisite storage period under normal temperature conditions, and then to examine the contents for any signs of deterioration.

Deterioration may manifest itself in a number of different ways, depending on the nature of the ingredients. It may be due to sedimentation of an inhibitory pigment, gelation of a semi-polymerized medium, syneresis of oil from a grease, etc., and with the possible exception of syneresis, where a weighted-cone stability test by the standard I.P. method will give useful information, accelerated tests based on storage at artificially elevated temperatures have met with comparatively little success, and must be employed with extreme caution.

The Testing of Different Classes of Temporary Corrosion Preventives.

Class A. *Oil Type Protectives.*

These materials normally consist of light mineral oils to which corrosion inhibitors have been added. They are frequently employed for short-term preservation during the course of manufacture, or for the preservation of small components packed loose and relying largely on the outer wrap or carton for their main protection. A special class of oil-type protective has been developed for the preservation of valve mechanisms and cylinder-bores of I.C. engines during storage or on laying up. In this latter class special additives, normally of a mild basic nature, are incorporated with a view to neutralizing the acidic residues left from the combustion of leaded fuels.

The protective properties of this class of material are, in general, inferior to those of the other classes, and for this reason the more conventional methods of testing for protection have, in general, been found to be too drastic and are not applicable. A technique has been worked out in the laboratories of the Chemical Inspectorate which is based on that quoted in B.S. 1391 and which was originally devised in the Armaments Research Department. This method involves spraying a mild-steel panel coated with the preservative oil with a dilute salt solution to a given droplet

density and then maintaining the panel in an atmosphere of high humidity to prevent evaporation. The test suffers from the disadvantage that it is sensitive to slight differences in technique, and extreme attention to detail is necessary if reproducible results are to be obtained. Full details of this test are given in the paper contributed by Mr Clinton.

In the case of I.C. engine preservation the protective employed has, in addition to its normal function, to neutralize the acidic residues left on valve mechanisms, etc., arising from the ethyl bromide (and, in Motor Mix, ethylene dichloride) used as a stabilizing agent in tetra-ethyl lead. For this reason a test has been devised in which the ability of the preservative to counteract the corrosive action of hydrobromic acid is measured. Full details of this test are given in D.T.D. specification 587.

The other tests normally carried out on oil-type protectives are viscosity, pour point, and flash point.

For these, and any other tests involving the physical properties of the material, satisfactory Institute of Petroleum methods already exist.

CLASS B. *Thin Film Soft Protectives—Solvent Deposited.*

Materials of this class normally consist of dispersions in a non-aqueous solvent of wool-fat derivatives, petrolatum, petroleum–oil mixtures, or soap-thickened oils, with or without the addition of soluble corrosion inhibitors. A special grade of material has been developed which has the property of displacing water from a metal surface by preferential wetting, thus rendering it suitable for use on articles, which, for any other reason, cannot be dried prior to preservation. Special tests have, of course, had to be developed to evaluate the properties of the water-displacing type.

So far as the non-water-displacing type is concerned there are, of course, certain obvious properties of the solvent which should be evaluated in order that toxicity, fire risk, etc., can be fairly assessed. Once the film has been deposited, however, the main property which requires evaluation is the protective value of the film, and from this point of view these materials can be considered to be in the same class as any other soft-film protective and similar testing techniques are applicable. In common with all other soft-film protectives, however, it is most important to ensure that once the film has been deposited it will remain *in situ* under the most severe conditions of temperature ever likely to be encountered in practice. A drop-point determination on the non-volatile residue will give useful information, but is, in certain circumstances, likely to be misleading; for example, the drop point of lanolin is in the region of 40° C, but lanolin films deposited on solid steel will show no signs of drainage at temperatures considerably in excess of this figure. It is advisable, therefore, always to test such materials quantitatively for drainage from a vertical metal surface maintained for several hours at a temperature slightly in excess of the maximum to be anticipated in practice.

The water-displacing types, on the other hand, require a somewhat specialized testing technique, if their properties are to be correctly assessed. The most important property to be expected from such a material is, as the description suggests, the power to displace water from a wet-metal surface. Whilst it might be possible to predict the water-displacing properties of such a fluid from a consideration of contact angles, surface

tension, etc., it is safer to rely in the end on a purely practical test, and details of such a test which is capable of quantitative reproduction are given in specification CS/2060A. In practice, it is found that water-displacing protectives of this type are liable to become emulsified with the water removed from the wet metal, and separation of water is necessary before the fluid can be re-used. For this reason it is usual to measure the demulsification properties of mixtures with water.

Once the water has been removed from the metal surface the water-displacing protective functions in exactly the same way as any other thin-film solvent-deposited type. Details of a test designed to measure both the protective properties of the residual film and the efficiency of removal of water from the metal are given in specification CS/2060A. In this test sodium chloride solution was employed to wet the metal surface in lieu of pure water, first, because water-displacing fluids of this type were frequently employed during the war for the immediate treatment of stores salvaged from the sea, and secondly, because the presence of sodium chloride in any residual water not removed by the fluid accelerates greatly the corrosion of the metal, thus enabling results to be obtained in a shorter time.

Finally, it should be borne in mind that in the process of demulsification from water, one or more of the essential constituents of the fluid might be leached out. It is always as well, therefore, to repeat all the above tests on a sample of the material recovered after separation from water with a view to ensuring that no deterioration has taken place.

CLASS C. *Thin Hard Film Protectives—Solvent Deposited.*

Materials falling into this category are of a variety of compositions; resin-hardened wool fat, plasticized bitumens, and certain metallic soaps being typical materials. They are applied from a solvent solution either by dipping or spraying, and as speed of drying is so frequently a factor controlling production, it is as well always to look very carefully at the solvents employed. Unfortunately, the more volatile solvents which are suitable for use in such compositions fall broadly into three classes, each of which is attended to a greater or less extent by hazards to personnel.

(1) There are the lighter-boiling petroleum fractions which are inevitably highly inflammable, and their use is therefore attended by a fire risk.

(2) There are the non-inflammable chlorinated hydrocarbons such as chloroform, trichlorethylene, dichlorethylene, carbon tetrachloride, and methylene chloride. These materials are all either toxic or narcotic if their fumes are not completely removed from the atmosphere. The use of such materials must therefore be associated with adequate ventilation and fume-extraction plant.

(3) Finally, there is the class of materials, such as benzene and certain other aromatic hydrocarbons, which are both toxic and highly inflammable.

The chemist evaluating a hard-film, solvent-deposited type of protective would therefore be well advised to look into the nature of the solvents employed in relation to the known conditions of usage, before proceeding further

with his examination. Viscosity determinations can provide a useful guide regarding the suitability of the material for application by dipping, and regular viscosity measurements of the material in the dipping-bath will enable accurate control to be exercised over the addition of thinners which must be made at regular intervals to replenish inevitable losses of volatile solvents due to evaporation. Unless this is done, unduly thick, uneven coatings will result. For such purposes an accurate determination in an Ostwald tube, or similar type, viscometer is quite unnecessary and the use of a flow cup similar to the Ford Cup so widely used in the paint industry is recommended. Such an instrument, together with its method of use and calibration, is at the moment being standardized by the British Standards Institution.

Having established that the material is suitable for application it is generally of vital interest to know the drying time, as on this factor the planning of the throughput of a factory is frequently based. Needless to say, any test for drying time is, in effect, largely a question of rate of evaporation of a solvent, and, if repetitive results are to be obtained, such tests must be carried out in a well-ventilated room which can be controlled to a constant temperature and humidity. The first stage of drying, commonly referred to as the surface drying time, is usually taken as the time at which the film is no longer wet or tacky enough to pick up particles of fluff, dust, etc., from the air. A suitable method of measuring this property is described in Appendix A of B.S. 256; in this test sand of definite particle size is sprinkled on the film and is then lightly brushed off with a camel-hair brush. The film is taken to be surface dry when a stage in reached that no sand remains adhering to the surface. The second stage of drying (and probably the most important from the users' point of view) is the time which must elapse before the preserved article can safely be handled and the primary wrap applied. Due to their nature and composition most hard-film temporary protectives do not dry " hard " in the same sense as a paint or varnish film and often display a permanent tack. It is a relatively easy matter to determine whether a film has become dry enough to handle without removal, but it is not so easy to decide whether the film is sufficiently tack-free. In the ideal preservative the protective would not, of course, adhere at all to the wrapping-paper, but in practice this is seldom achieved, and the important point is to ensure that the preservative film does not adhere so strongly to the wrap that subsequent handling of the wrapped article results in stripping of the preservative from the metal surface. There is no well-established test which can measure this property, which depends on the relative strengths of the metal-preservative and preservative–wrapping-paper bonds. As these will vary from metal to metal and paper to paper, there would appear to be little alternative to the existing practice of employing an essentially practical test. In this test the wrapping-paper is placed in intimate contact with the preservative film under a loading of 1 p.s.i. for a given period of time. At the end of this time the load is removed, and the paper should be capable of being completely stripped away without exposing any of the metal surface.

There is always the danger that in producing a rapid-drying, tack-free film, platicizers will be reduced to a minimum, and a brittle coating will result. It is as well, therefore, to measure the flexibility and adhesion of

the dried film of material, and this is normally done by bending a panel coated with the preservative through 180° over a mandrel of specified diameter. It should be borne in mind that thickness and type of metal substrate, rapidity and temperature of bending, all play a most important role, and scrupulous attention to detail is essential if reproducible results are to be obtained.

The hardness of the dried film has in the past normally been assessed in the standard paint scratch-hardness tester, in which a hemispherical hardened steel or tungsten carbide scratching point is placed in contact with the film under a specified loading, the film is then drawn under the loaded scratching point at a controlled speed, and the loading required to give penetration of the film is taken as a measure of its hardness. Unfortunately, certain plastic and relatively soft coatings will take quite high loadings before actual penetration takes place, and results are at times apt to be misleading. It would appear therefore that there is room for the development of some new test which will measure more accurately the true hardness of the coating, and in this connexion the use of the Sward Hardness Pendulum Rocker, which should be capable of measuring both hardness and tack-freedom, would appear to be worthy of consideration and trial.

So far as the protective properties of hard-film preservatives are concerned, the methods of test follow the conventional lines. It should be borne in mind, however, that users may be under the impression that because the coating dries with a varnish-like surface it will of necessity possess the same exterior durability as a paint or varnish film. Many of the preservatives in this class, whilst possessing excellent protective properties under the normal conditions of deterioration encountered in a packed store, will in fact break down very rapidly indeed if exposed for any length of time to the combined destructive influence of rain, actinic light, and rapid temperature change. If, therefore, it is known that a hard-film preservative is expected to give protection under such conditions (*e.g.*, open storage on site, etc.) it is advisable to test for exterior durability either by conducting a long-term exposure out of doors (this is always fraught with grave dangers due to seasonal variations and the vagaries of the British climate) or by exposing a coated panel for at least 250 hr (preferably 500 hr) in an accelerated-weathering apparatus such as that described in Appendix C of B.S. 987. The principal defects to be looked for in such a test are chalking and erosion, checking, splitting, or any other form of cracking, and of course corrosion of the steel substrate.

CLASS D. *Thick Soft Film Protectives.*

Materials in this class are of three main types. First, there are compounds based on petrolatum with or without compounding agents or corrosion inhibitors. These materials are normally applied molten from a dipping bath, and from this point of view a knowledge of the drop point and the viscosity of the molten material is valuable. Once the film has solidified after removal from the dipping-bath, it should have sufficient rigidity to withstand the manual application of a grease-proof wrap without undue thinning of the film at points of contact; in this connexion the material should also not be too rigid, or removability may be impaired, and high torques may be set up when a preserved article, such as a ball bearing, is

first taken into use. A determination of the unworked penetration is desirable from both these points of view.

Secondly, there are grease-like materials, *e.g.*, lime- or barium-base greases, based on wool-grease stearin. Such greases are generally applied by hand smearing, and, apart from the normal tests applied to assess their protective properties, the conventional tests for greases already covered by Institute of Petroleum standard methods should be adequate to control the quality of supplies.

Finally, there are the so-called "slushing compounds" which are normally grease-like materials reduced to a comparatively mobile consistency by the addition of volatile solvents. These compounds are normally applied by slushing or brushing, and should possess sufficient flow to enable brush-marks to be virtually eliminated before the solvent has evaporated to such a degree as to prevent further flow. A purely practical test should readily enable this aspect to be covered. There is always a danger with this type of compound that an excessive quantity of thinners may be added, and unless it is proposed to control this by limitations on composition it is desirable to ensure that an adequately thick coating can be applied to a vertical metal surface without flowing off.

Finally, it must be borne in mind that a great many of the petrolatums otherwise suitable for preservation purposes melt at temperatures appreciably lower than the temperature likely to be reached in the hold of a vessel passing through the Red Sea or in tropical areas. There is a danger, therefore, that an article adequately preserved in the U.K. may reach its destination with the protective film melted and run away from vital areas. A knowledge of drop point may give a fair indication as to whether the material is likely to be suitable from this point of view, but may lead to doubt due to the fact that drop points of petrolatum normally available in quantity are unlikely to exceed, by more than a few degrees at the most, the tropical temperatures likely to be encountered. As for the soft-film, solvent-deposited types in Class B, therefore, it is as well to check this very important characteristic by means of a drainage test from a vertical panel maintained at an elevated temperature for some hours.

CLASS E. *Strippable Coatings. Thin or Thick.*

All these materials are of comparatively recent development, and, as the protectives offer considerable advantage to the user from the point of view of appearance, handleability, ease of removal, and protection (both from the point of view of corrosion and cushioning against mechanical damage), they are likely to be developed to a much greater extent in the future. Up to date the most successful coatings developed in the U.K. have been based on ethyl cellulose compounded with waxes and two oils (one a plasticizing oil and the other designed to exude). Similar compounds based on cellulose acetatebutyrate have found a market in the U.S.A. and solvent-deposited varieties are also in common use where a thinner film with a lower order of protection is acceptable. Finally, there are compounds based on rubber-latex emulsions containing sodium benzoate as a rust inhibitor, which are, however, still in the experimental stage in the U.K.

In the present paper, however, comments will be restricted to the ethyl cellulose hot-dip types, which are undoubtedly in much the most common

use, and it is felt that testing techniques applicable to this grade are likely to be similar for other compounds if and when they come into use.

Ethyl cellulose dip coatings are applied molten from a thermostatically controlled, oil-jacketed, dipping-bath. Unfortunately, the melting point of such compounds is high, being of the order 165° C, and the decomposition temperature is not much higher, being in the region of 200° C. Due to the time it takes an oil-jacketed bath to reach the requisite dipping temperature, it is common practice to leave the baths on low-temperature heating overnight, and unless there is an exceptionally high turnover, the compound may be many days in the molten state prior to application. Makers of such compounds normally incorporate oxidation inhibitors with a view to ensuring good thermal stability, but any testing carried out should cover this point most carefully, as it is vital to know, not only what performance is to be expected from the freshly supplied compound, but also what its properties will be after storage in a dipping tank for considerable periods at temperatures in excess of its melting point.

The majority of the tests on hot-dip strippable coatings relate to the properties of the film, and from this point of view it is convenient to dip a mild-steel panel in the material for a period of 5 sec at a temperature of 190° C. After removal from the dipping-bath, the film is allowed to cool, stripped from the panel, and then tested for transparency and colour (from the point of view of appearance and legibility of markings, labels, etc., under the coating), uniformity of thickness (this is important from the point of view of cushioning as well as protection), tensile strength, and elongation at break (the method described in B.S. 903, Part 2(B), Method 3, Section C, using a rate of traverse of the lower grip of 100 mm per sec has been found to give reproducible results), and oil exudation (it being desirable that the coating should exude oil, but that exudation should not be excessive).

The strippability should, of course, be carefully checked on both freshly prepared and aged panels, it being essential that the coating should come away cleanly in one piece without leaving anything but a thin, oily film on the surface of the metal.

A measure of the compressibility of the material is conveniently carried out on small plugs of the plastic, it being desirable that under pressure no cracking or splitting of the coating shall occur.

In the application of hot-dip strippable coatings two methods are commonly used :—

(*a*) The article to be preserved is suspended from a thin wire, dipped, cooled, and the wire then cut off short, the point of entry of the wire being heat sealed by means of a soldering iron.

(*b*) With certain articles, where the shape is convenient, *e.g.*, a twist drill, one end is dipped to a little over half its length and the coating allowed to cool, the other end is then dipped so that there is an overlap of at least ½ in. In this way heat sealing of suspension points is avoided.

Where Method (*b*) is employed there is, of course, a point of weakness in the coating at the overlap, and an incorrectly formulated coating may crack or separate at the point of juncture. Furthermore, it will always be found that the coating is perceptibly thinner in the vicinity of sharp edges, and

here again there is a point of weakness. It is usual, therefore, to prepare a test specimen with an overlap and then to subject this to thermal shock by exposing it alternately to the highest and lowest temperatures likely to be encountered in practice, observing any tendency to cracking or separation at the overlap.

Due to the high dipping temperature and the fact that the exuding oil used in the formulation is usually a low-viscosity type, there is, of course, always a fire risk, and from this point of view it is customary to check up on the fire point of the material (the I.P. standard method being appropriate here).

So far as protective properties are concerned humidity cabinet exposures and salt-water immersion tests have been found to give reliable results, but such tests must necessarily be conducted over very considerable periods if the extremely high standard of protection which one has a right to expect from this type of coating is to be ensured.

Acknowledgment.

The author is indebted to the Chief Scientist, Ministry of Supply, for permission to present this paper.

Discussion.

Afternoon Session.

Dr W. H. J. Vernon, opening the afternoon discussion, congratulated the Protectives Panel on the work already done, and continued :

It is noteworthy that the methods of testing we have to consider are very largely accelerated methods. We may well ask, therefore, what is the criterion of a satisfactory accelerated test? If we were dealing with unprotected metal my answer would be the reproduction, on a compressed time scale, of the same form of corrosion/time curve as would be realized under extended conditions of exposure in service. In practice, in dealing with the appraisal of temporary corrosion preventives, probably a more convenient criterion is that the accelerated test shall place a given series of protectives in the same order of efficiency, and showing the same mode of breakdown, as would be found after much longer periods of service.

How is the acceleration to be achieved? Here the golden rule must surely be that, whilst it is permissible to accentuate any factor that is present under service conditions, one must be very cautious indeed about introducing an entirely new factor, *i.e.*, a factor that is not present under service conditions.

Another point about the tests under discussion is that they all refer to atmospheric conditions and not to conditions of immersion. Here it may be remarked that it is, in general, more difficult to devise a satisfactory accelerated test for atmospheric than for immersed conditions. In immersed corrosion (I have in mind the more general case of neutral solutions or natural waters) the *controlling factor* is almost invariably the rate of supply of oxygen to the metal surface. Under service conditions the rate of supply of oxygen normally falls far short of that required for the theoretical maximum rate of corrosion. Here, therefore, we have a con-

venient method of acceleration ready to hand: all we have to do is to increase the rate of supply of oxygen—and that, in fact, is the basis of most accelerated immersed corrosion tests.

In atmospheric corrosion, on the other hand, this simple method is clearly not available, since of necessity there must always be ample excess of oxygen under normal service conditions. Here, therefore, we must look for other factors to accentuate in our accelerated test.

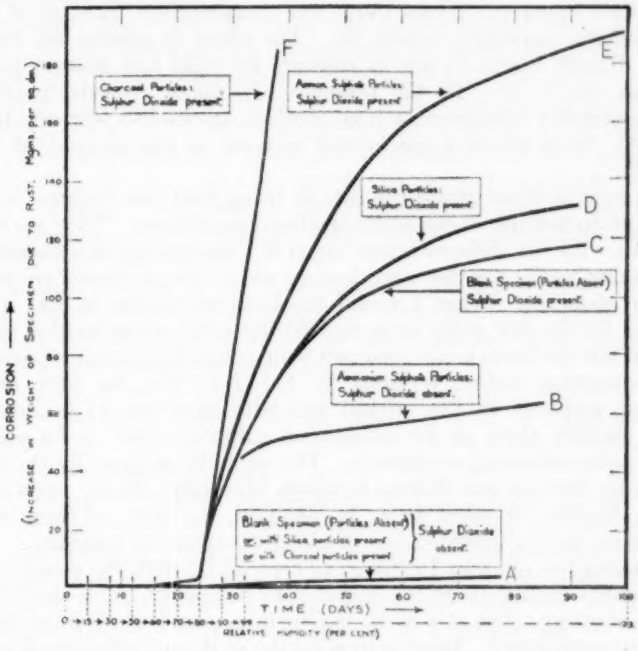
CORROSION
(INCREASE IN WEIGHT OF SPECIMEN DUE TO RUST, Mgms per sq dm)
Charcoal Particles: Sulphur Dioxide present
Ammon. Sulphate Particles: Sulphur Dioxide present
Silica Particles: Sulphur Dioxide present
Blank Specimen (Particles Absent) Sulphur Dioxide present
Ammonium Sulphate Particles: Sulphur Dioxide absent
Blank Specimen (Particles Absent) or with Silica particles present or with Charcoal particles present
Sulphur Dioxide absent
F
E
D
C
B
A
TIME (DAYS)
RELATIVE HUMIDITY (PER CENT)

FIG. 1.

INFLUENCE OF PARTICLES ON RUSTING OF IRON WITH AND WITHOUT PRESENCE OF SULPHUR DIOXIDE. RELATIVE HUMIDITY INCREASED IN STEPS, AS SHOWN, TO MAXIMUM OF 99 PER CENT.

Within necessarily brief limits there are one or two points I would venture to put before the meeting, because there would seem to be some danger of their being overlooked. These points are probably sufficiently epitomized in Fig. 1,* which illustrates the corrosion behaviour of (unprotected) specimens of mild steel in atmospheres of progressively increasing relative humidity. Two important principles emerge from these results.

(1) *The principle of critical humidity.* It will be seen that, for a number of different kinds of atmospheric pollution, no corrosion at all occurs at relative humidities below *ca* 50 per cent. In the presence of atmospheric pollution as shown, some superficial rusting occurs between this value and

* Vernon, W. H. J. *Trans. Faraday Soc.*, 1935, **31**, 1692; *Proc. Chem. Eng. Gr., Soc. Chem. Ind.*, 1937, **19**, 18.

ca 80 per cent R.H., but it is quantitatively trivial; at the higher value, the effect is outstanding, the rate of rusting (depending upon the type of atmospheric pollution) increasing many times.

(2) *Influence of atmospheric pollution.* In the absence of both gaseous and solid pollution the effect of increasing humidity is negligible, even at the higher humidities; this is true also in the presence of inert solid particles (*e.g.*, charcoal) provided that sulphur dioxide is absent (curve A). Solid pollution alone (*e.g.*, disperse particles of ammonium sulphate, a common atmospheric impurity) brings about the characteristic increase of rusting at the critical humidity (curve B). The effect is greater for traces of sulphur dioxide (curve C) and is additive for solid and gaseous pollution conjointly (curve E). In the presence of sulphur dioxide, particles of highly adsorptive substance such as charcoal, themselves intrinsically inert (curve A), bring about a spectacular increase in the amount of rusting (curve F).

These results demonstrate the sort of thing that can happen to inadequately protected specimens under sheltered conditions. They are entirely consistent with the differentiation urged by Clinton between conditions of full exposure to the weather and those in which the specimens are screened from the elements. What I would especially emphasize is that it is not necessary for the dew point to be reached for quite serious rusting to occur, provided the specimen is not screened from suspended disperse particles.

An interesting feature revealed by Fig. 1 is that the form of curve (including response to the critical humidity phenomena) is similar for sulphur dioxide alone as for ammonium sulphate alone or for solid and gaseous pollution acting conjointly. This provides support for the method adopted by Preston and Stroud in which they rely entirely upon sulphur dioxide—bearing in mind that, in addition, the test of these authors incorporates actual condensation of moisture upon the specimen.

In opening my remarks I referred to correlation with the results of tests under service conditions as the criterion to be applied to accelerated tests in the laboratory; but this raises the further question, what do we mean by service conditions? Bearing in mind the profound influence of environment it is clear that we cannot expect any one accelerated test to reproduce all conditions of service. We should therefore remember—particularly in studying the papers in this symposium—that differences between any two tests do not necessarily reflect adversely upon either. Some compromise obviously is necessary, and we should aim at agreeing upon a minimum number of representative tests to cover such a range of service conditions as may be reasonably anticipated.

Turning to the papers themselves, there is time to raise only a few points.

Clayton and Thompson, in referring to newer types of temporary protectives, do not include those based on inhibited rubber latex. Apropos of the authors' reference to sodium benzoate and sodium nitrite as individual corrosion inhibitors in aqueous solution I should like to emphasize the great advantage that may arise in many cases from using the two inhibitors conjointly. The authors enumerate a number of cogent questions. On the question whether salt spray is permissible to represent acceleration of plain-water corrosion, one might counter "what does the author mean by

'plain water'?" (I shall refer presently to the use of distilled water.) I would say that salt spray is permissible and entirely logical if traces of salt spray or even of marine air may be expected to gain access during service. Otherwise considerable caution should be exercised. Concerning whether it is permissible to use mild steel specimens to represent the general run of ferrous materials, it may be observed that recent American work has shown that the familiar repressive effect of copper on the corrosion of mild steel in industrial atmospheres is exerted by far smaller concentrations of copper than had previously been suspected, and it has therefore been recommended (in order to overcome the vagaries arising from small and variable differences of copper content in commercial mild steel) to use, in atmospheric corrosion tests, control specimens containing a definite concentration of added copper (*e.g.*, 0·3 per cent). As to the influence of surface finish, earlier work * has shown that immediately after preparation the surface of steel is in a sensitive condition, but develops a measure of immunity if exposed to air under screened conditions such that a surface oxide film can develop without interference by atmospheric nuclei. This point is covered by the procedure adopted by Hoar and Smith.

Clinton gives us much useful information on humidity cabinet technique, but one would welcome more details as to the results actually obtained. Clinton also sets out a number of very useful and very sound points that should be taken to heart in work of this kind.

Pohl's excellent paper affords the opportunity to pay tribute to the invaluable work carried out by him and his associates on water-displacing protectives. He has made some valuable comparisons between the weatherometer method and the humidity cabinet method. I agree with him on the generally greater reproducibility of the weatherometer as compared with the simple humidity cabinet. Except in relation to *inland* tropical conditions it is difficult to see how high relative humidity, *per se*, can satisfy any of the criteria for an accelerated test which I enumerated at the outset. One would like to congratulate the author on the valuable graphical methods of which he has made such excellent use.

The conditions simulated in the work described by Preston and Stroud are essentially those of industrial atmospheres, but one must bear in mind the ubiquity of sulphur dioxide in the atmosphere in this country. Even in the most rural districts there is evidence that SO_2 plays the predominant part in atmospheric corrosion. When urban and marine conditions coincide, it has been within my experience that the urban component has invariably much the greater influence.

The technique employed by Hoar and Smith differs in principle from those of other authors in the symposium and raises a matter of considerable interest. Instead of intensifying the corrosiveness of the environment the authors set out to achieve the same result by reducing the thickness of the coating. In principle there is much to be said for this, and up to a point I am in agreement with the authors. At the Chemical Research Laboratory, in the testing of paint coatings under immersed conditions, we have used thinner coatings than would be used in service and have sometimes been criticized (not altogether justifiably) for so doing; but in our tests we

* Vernon, W. H. J. *Trans. Faraday Soc.*, 1927, **23**, 1590.

reduced the thickness only by about half and, moreover, the thinner coatings were applied by methods precisely analogous to those used in service. Hoar and Smith, on the other hand, used coatings that are excessively thin (of a different order of thickness), and this would appear to give rise to possible difficulties associated with fringing effects. My feeling is that the authors' principle is sound, but they have pushed it rather too far. Again I am not altogether happy about the use of distilled water because of its liability to vary in composition and corrosiveness. It would seem sounder to use thin films of liquid the conductivity of which is definite and reproducible. The greater mean corrosiveness of such a liquid would then permit the use of rather thicker coatings for the same period of test. Personally I would prefer to meet the authors in the spirit rather than in the letter, *i.e.*, by the use of relatively thin coatings applied by normal methods and a reproducible environment that will produce breakdown of the coating within a reasonably short time.

Dr E. E. Longhurst: My remarks are limited to amplifying the points made by Dr Clarke and myself on the method of preparation of steel test panels, commonly used in the testing of temporary corrosion preventives.

A number of earlier authors have discussed the role played by inclusions, etc., exposed at a steel surface, in initiating rusting when the steel is exposed to corrosive atmospheres.

It is probably well known that mild steel sheet, such as is used for test panels in the majority of tests now being discussed, is produced from, "rimming" steel. This steel has a thin surface layer of relatively pure iron. Non-metallic inclusions in the steel are distributed in the body of the steel below the surface skin of pure metal. A severe abrasive treatment of the sheet steel, by penetrating the surface skin and exposing inclusions in the impure steel below, may thus give rise to variable and misleading results in subsequent corrosion tests. To illustrate the wide range of quality of mild steel sheet, having reasonably good surface finish and therefore suitable for use as specimens in corrosion tests, I have prepared microsections of two typical mild steel sheets.

Fig. 2 (A) shows a polished, unetched, microsection of a typical tinplate steel. The composition of this steel conforms to B.S. 970/EN2B, a specification only a little less rigid than that covering good deep-drawing steel sheet materials, viz., B.S. 970/EN2A/1. The section shown on the screen corresponds to a thickness of steel of about 0·007 inch. The double black line at the top is a thin layer of copper, deposited on the steel before sectioning to preserve the edge of the steel during the subsequent polishing operation. The dark patches in the main body of the steel are non-metallic inclusions of oxides, sulphides, etc. The thin layer of pure iron at the surface of this steel is approx 0·003 inch thick, and, as this slide shows, can contain small particles of impurities which reduce the thickness of the surface layer locally. It will be appreciated that a severe abrasion of the surface of such a steel as this will stand a very good chance of exposing the impurities in the lower layers, either by removal of the pure iron layer or by deep scratches scoring through to the impure steel core.

Fig. 2 (B) shows a rather better condition. This is an unetched microsection of an extremely pure steel of deep-drawing quality. Being a

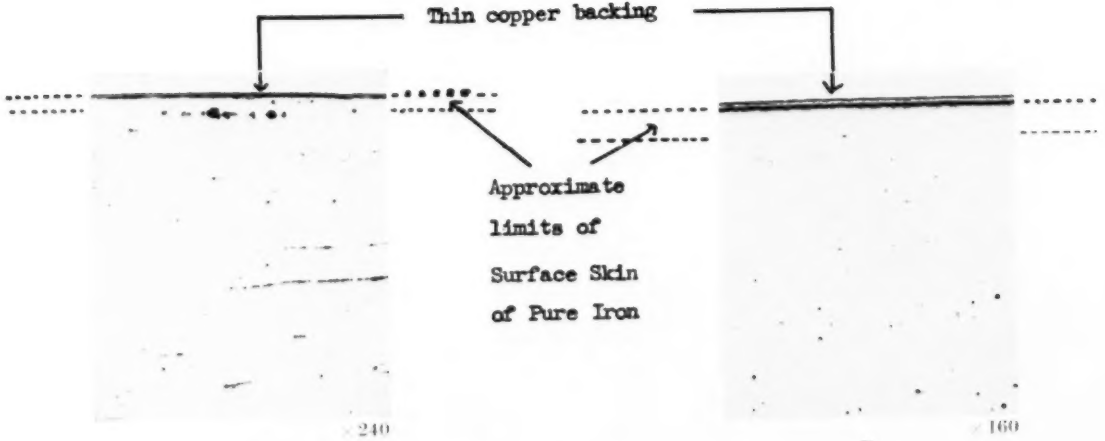

FIG. 2.

POLISHED MICROSECTIONS, UNETCHED, OF TWO THIN-SECTION SHEETS OF MILD STEEL, SHOWING NON-METALLIC INCLUSIONS.

A. Tinplate steel, 30 gauge. Thickness of pure iron skin, approx 0·003 inch. Relative large amount of inclusions. Composition of steel conforms to B.S.970/EN2B, and is just outside the limits required by B.S.970/EN2A/1.

B. Good quality, deep drawing steel, 20 gauge. Thickness of pure iron skin, approx 0·001 inch. Relatively small amount of inclusions. Composition of steel conforms to B.S.970/EN2A/1.

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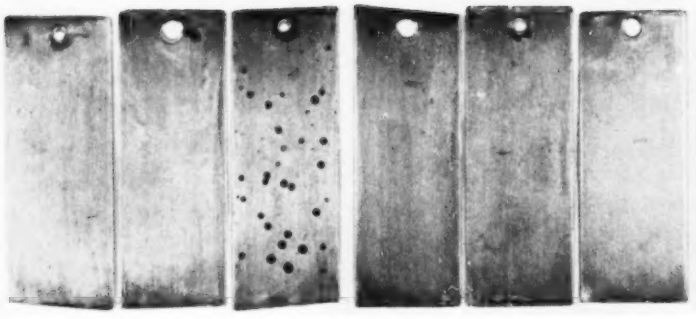
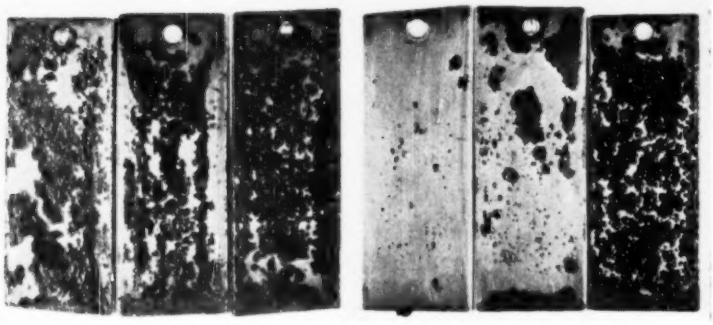


1·0% 0·5% 0·17% 1·0% 0·5% 0·1%

Sodium benzoate additions. Sodium nitrite additions.

FIG. 5.

CONDITION OF SPECIMENS AFTER 24 HOURS IN NORMAL ATMOSPHERE.



1·0% 0·5% 0·1% 1·0% 0·5% 0·1%

Sodium benzoate additions. Sodium nitrite additions.

FIG. 6.

CONDITION OF SPECIMENS AFTER 200 HOURS AT 120° F AND 100 PER CENT R.H.

rather thicker steel the surface layer of pure iron is also thicker, in this section approx 0·001 inch thick, the thickness of steel shown in the figure being about 0·011 inch. Very few inclusions are present in the lower layers of steel, and those present are very small. Thus, removal of the surface layers, as a whole or locally by deep scoring, will not result in the uncovering of large amounts of inclusions.

I do not want to go on record as saying that the testing of specimens having inclusions at the surface is itself a bad thing. What we must bear in mind is that the quality of the steel used may vary considerably from one batch to another. If the results of tests carried out at different times, or by different investigators, are to be compared, then the method of surface preparation used for the steel test panels should be such that similar surfaces are produced. Since the mild steels used all possess this pure iron surface layer, it seems advisable to employ a method of preparation which will preserve this surface layer intact.

J. S. Box : On this question of the use of lamellar steel I think there are many here who will agree that the thickness of the layer is a function of the thickness of the material. I suggest we should consider using specimens of the order of $\frac{1}{32}$ inch thick, because one can be reasonably sure then of a surface layer of 0·005 to 0·010 inch thick, and thus avoid the possibility of having inclusions going through the surface. Personally, I prefer to use cold-rolled specimens unprepared other than solvent de-greasing.

T. G. Clinton : Regarding the question of abrasion of the surface, it may be of interest that we feel that our method of abrasion removes approximately 0·0001 inch of the surface, and the specimens we are using are 0·045 inch thick. We know we are well within the thickness of the clean steel.

Dr S. G. Clarke : I can probably relieve Mr Clinton's mind very much on this question of abrasive cleaning steel sheet specimens. I think he has referred to specimens which have been used by the Protectives Panel. There the steel used was very carefully selected and was very similar to that shown by Dr Longhurst on his second slide. A certain amount of abrasion is, therefore, very unlikely in that particular steel to give any appreciable ill effect.

Mr Box suggested using a rather thicker steel with a pure layer on it of 0·005 inch. Actually our examination of such a steel suggests that the layer is somewhat thinner than that, and for a thickness of the order given the layer would not be much more than 0·001 inch. It is difficult, however, to lay down any very definite figure for it.

Further, on this matter of abrasion, the abrasive used is very often what is known as " 0 emery cloth ". If the British Standard specification for this is examined, it will be seen that it allows quite a wide variation in the particle size of the abrasive, and some particles can be as much as 0·0035 inch in size. Hence it might conceivably produce a certain amount of scratching through a 0·001 inch layer. That, I think, would be dangerous to use on a dirty steel (if I might use the term) such as Dr Longhurst showed

in his first slide. But, as I said before, it would not be likely to produce much ill effect with the higher qualities of steel.

E. G. Stroud: There are two points in Dr Hoar's paper to which I should like to refer. One is the use of carbon tetrachloride and chloroform for the cleaning of specimens; our experience shows that they can, themselves, give rise to corrosion, due to the tendency for the formation of hydrochloric acid on exposure to light and air.

We carried out experiments using two specimens of copper which had been electro-polished; one was washed in very pure benzene (as used for molecular-weight determination) and the other in the purest carbon tetrachloride available. Both specimens were examined by electron-diffraction; that washed in benzene gave the normal metal pattern, that from carbon tetrachloride showed much impurity on the surface. We have since avoided the use of chlorinated hydrocarbons and relied on pure benzene.

The other factor concerns the use of calcium chloride in desiccators. We view this material with strong suspicion because, even with the purest reagent, hydrochloric acid can be detected in the vapour above it. This may explain why the reproducibility is, at times, not good. We prefer to use flake caustic soda.

Dr D. Wyllie: On the points Dr Hoar and his colleague have raised I would like to ask what difference they have found between specimens prepared by cleaning and degreasing, and used as quickly as possible, and specimens cleaned, degreased, and treated by their special method to form a strong oxide coating before use? The point is of importance in the later discussion of the reaction of the solvent and additives with the oxide layer, in particular the preferential absorption of polar groups on that layer. The authors remark that the ideal concentration of inhibitor is that which will form an oriented monolayer at the oxide-film surface leaving very little inhibitor in the bulk of the protective. From the point of view of the worker who is formulating new materials this is a valuable conception, but I can see a difficulty in estimating the conditions correctly when as frequently happens in the testing of protectives one is unaware of the precise formula of the material under examination.

Dr Longhurst: Has it been shown whether these polar molecules adsorb more strongly at an oxide film than at a plain metal surface? I believe that a lot of American work has been done with platinum specimens, carefully burnt off to remove traces of grease. Such a surface would have no air-formed oxide film.

Dr Clayton: There is no doubt that reaction with an oxide layer is a very important feature of boundary lubrication. It is probably equally important with temporary corrosion preventives. Should these two ageing processes always be done: the building up of the oxide layer and the promotion of reaction between the corrosion preventive and the oxide layer?

T. G. Clinton: I feel that it is dependent on a knowledge of the material in question. If it is a material which is likely to oxidize, the ageing period

would be almost essential to get a true picture. If it is an inert material one could possibly dispense with it.

V. W. DAVID : When preparing films with compositions of the solvent-deposited type it is necessary to allow sufficient time for the solvent to evaporate before starting the exposure tests. A period of 24 hours is probably enough.

A. E. MCAULAY : I feel that an ageing test is of importance, but in practice protectives are often applied to metal parts in exposed places or out-of-doors, where weathering may commence almost immediately after application. It would perhaps be as well, therefore, to consider the effects of weathering immediately after application of the protective (time, of course, being allowed for evaporation of the solvent in the case of solvent-type protectives) so that it would be unwise to attach too much importance to the properties of the protective after a period of ageing.

DR LONGHURST : These corrosion preventives are not normally used under conditions which encourage rapid ageing, such as might be produced by exposure to oxygen and ultra-violet light. In the present state of knowledge as to the rate of ageing of these materials in service, I doubt the advisability of artificially ageing these materials before testing. For example, the results given in Table II of our paper show that D.T.D.663 material, which can age appreciably under certain conditions, was inferior to C.S.1033 materials on full exposure outdoors for eight months. When subject to sheltered exposure outdoors, however, the D.T.D. material behaved at least as well as the C.S. materials.

R. ST. J. PRESTON : The matter of ageing to which previous speakers have referred is concerned with the completeness of evaporation of the solvent holding the protective. It is clearly advisable to fix for specification purposes the temperature and time of this period, before testing.

Another feature of ageing, however, which must have an important bearing on the behaviour of a protective coating is the gradual setting of the film which occurs during the early life of many types of protective. Too early exposure to a severe atmosphere before this induration period is completed could cause premature breakdown. A week or so of normal atmospheric exposure before the test proper begins would be helpful in ensuring a more equitable starting basis. By this means the early failure that could occur when a weak type of protective is exposed in an accelerated test " atmosphere " may be avoided, and a more representative result for its value obtained.

As a " normal " atmosphere one might specify a shed or louvred box situated outdoors, or an indoor atmosphere, or a controlled test atmosphere.

S. E. BOWREY : In considering the tests for temporary protectives which have been described, it will be immediately apparent that a great amount of work has gone into the development of reliable methods. As in other fields, the user is confronted with the problem of relating the laboratory test report to his actual needs, and in the field of corrosion prevention one

of the difficulties is to forecast with any degree of precision the conditions to be encountered.

It is interesting to observe how short a time is required for corrosion to take place under favourable conditions, and yet how long a period can elapse, even in Great Britain, without such conditions arising. It has been pointed out that in comparative tests some protectives show up best when condensation is severe, whilst others score when there is less condensation, the order of merit being altered by a change in the conditions. If a sufficient number of records could be obtained showing how often and to what extent condensation occurs in a variety of circumstances, say during a voyage to New Zealand, during storage in the tropics, in Great Britain, and so on, they would be useful in interpreting the results of field trials and in devising laboratory test procedures to simulate service conditions.

It is, of course, impracticable to employ human observers to the required extent, or even to utilize recording hygrometers. We are making some preliminary trials of a simple and robust device involving the exposure of paper tape carrying spots of colour which spread when moistened. The tape passes over a suitably shaped piece of solid metal which condenses moisture and spreads the spots on the paper when condensation occurs. The paper is moved at the rate of a few inches per day by a clock mechanism, which can be mains driven or battery operated. The intention is to place this instrument with various consignments of goods in store or transit, together with unprotected metal test pieces.

T. M. Taylor : A great deal of experimental work and much accumulated experience has formed the basis for the papers presented at this symposium, and I feel that they serve to emphasize the unsatisfactory position regarding performance evaluation of temporary corrosion preventives and the magnitude of the task before the Protectives Panel in developing and standardizing suitable test methods.

The first requirement of a performance test method is that it will correlate with field behaviour. The Panel is doing the right thing in obtaining field performance data from a number of different types of locations in order to check on the results of the tests carried out in a number of co-operating laboratories.

The second requirement is good repeatability and reproducibility. The lack of precision in methods for evaluating protectives resulted in the Services specifying either fixed compositions or that acceptance would be based on tests in an approval laboratory. Both these factors hinder development of new and improved protectives, but cannot safely be replaced until established methods of evaluation are available. Even when setting up equipment similar to that of the approval laboratory and carrying out tests under the same conditions, it has frequently been found that a product apparently superior to an already approved product has been rejected by the approval laboratory, *i.e.*, reproducibility is bad. This, however, is not surprising in the light of some of the data now presented. If a method is not repeatable, what chance has it of being reproducible ?

Table IV in Pohl's paper shows good repeatability between duplicate tests carried out together in the weatherometer but with relatively poor correlation between one set of runs and another (accordingly this means many

tests are required to give a reasonable rating). There is a similar but less-marked trend in the humidity cabinet results reported in Table VIII of the same paper. These results and a similar observation by Hoar and Smith suggest that the tests might be made repeatable if some factor at present not realized can be controlled. As this effect is observed in different types of test, this factor may be inherent in the preparation of the treated test pieces and could perhaps be checked by preparing simultaneously a number of coated test pieces for several series of weatherometer tests.

Performance can be influenced at the application stage, as is shown by Preston and Stroud, where it will be noted that the diluted petrolatum plus glyceryl-mono-oleate applied by a cold dip at room temperature gives superior performance both in the field and laboratory tests to the non-diluted material applied by hot dipping—this despite the fact that the diluted protective gives a film of only about one-third the thickness of that of the inhibited petrolatum. These results also support the view that temporary corrosion preventives should be evaluated in the form in which they will normally be used. The work of Hoar and Smith using very dilute solutions of protective material may be of use in development work, but the ultimate evaluation should be on the finished product applied by its appropriate method. As other authors have shown, the thickness of the protective film is normally a major factor in the degree of protection afforded.

In practice the degree of rusting that can be tolerated will vary with the nature and use of the article protected. Discussions at exhibitions of equipment that has been brought back from the tropics show that quite widely divergent views are held on this matter. One may say that the extent of rusting on a particular specimen is sufficient to reduce it to the category of scrap, whereas others may say that it needs only a brush up to make it serviceable.

The criteria for failure reported in the papers include initial rust, one spot per square inch, 0·1 per cent, 5 per cent, up to 100 per cent. Rusting at the edges may or may not be excluded. In some cases observations are made with the naked eye, in others under magnification. Apart from difficulties in observing incipient rusting underneath the film of corrosion preventive, personal factors play an important part—*i.e.*, when does a pinpoint of rust become a rust spot? The information given by Preston and Stroud (Table III) indicates that the quantitative determination of the loss in weight after a fixed period gives a very similar rating to that based on the time to failure assessed visually.

The test developed by Preston and Stroud appears to offer considerable promise for the evaluation of temporary corrosion preventives. It is a form of humidity cabinet test in which the presence of sulphur dioxide, whilst accelerating corrosion, may also serve to minimize effects due to variation in laboratory atmosphere. Field performance of temporary corrosion preventives is markedly influenced by atmospheric pollution and the variations experienced in the laboratory testing of protectives are sometimes alleged to be due to contaminants in the air. It may even be desirable in humidity cabinet tests to use chemically purified air with subsequent controlled addition of corrosive actuators.

I shall be interested to learn whether the repeatability of the method is satisfactory and whether there is any significance to be attached to the fact

that in a number of cases protected plates gave higher weight losses than the corresponding blank plates without protective. Perhaps a milder form of the test would be more applicable to oil-type protectives.

Clinton suggests that insistence on any particular design of cabinet can be avoided. It is, I understand, rather rare to find two identical humidity cabinets, and it seems to be assumed that, provided certain guiding principles are followed, differences in design will not affect the test results. I wonder if this is a valid assumption? The necessity for rigid adherence to details of apparatus and procedure in order to obtain good repeatability and reproducibility in the testing of petroleum products is well known.

The selection of different types of temporary corrosion preventive, *e.g.*, soft film/hot dip, soft film/solvent deposited, hard film/solvent deposited, and oil types, which can be expected to give a wide range of protective performance, have been used (and are being used by the Protectives Panel) in the development of test procedures. However, an acceptable method must do more than place these in their correct order as regards field performance. The method will be included in specifications and must be capable of differentiating between products of the same type with very much narrower range of performance. Thus, Clarke and Longhurst include a C.S. 1663B oil in the table in the Section on Correlation between the Tests, and this helps to give a Spearman coefficient to suggest correlation between salt-spray tests and outdoor-exposure tests. However, when the method is applied to a number of oil-type protectives the Spearman coefficient falls to −0·4 and −0·65. The authors dismiss this as of little importance, but it would have been useful if they could have included some data on more sheltered exposure tests to substantiate the inclusion of the salt-spray test in the C.S. 1663F specification for protective oils. In passing, I would mention that while the salt-spray test appears to be of good repeatability, reproducibility is bad; for example, in some recent tests the time to fail in one laboratory was approximately five times that obtained by another laboratory.

W. Pohl: Mr Taylor referred to the effect on performance, in both field experiments and laboratory tests, of the method of application; he called attention to the difference between petrolatum plus glyceryl-mono-oleate as a thick film and as a thin film. Application can and probably does affect performance, but an explanation of the particular example is a somewhat peculiar one. We wanted to compare pure petrolatum with petrolatum plus an inhibitor in this series of tests, and G.M.O. was selected as the additive. On hot dipping plates in the petrolatum and G.M.O., the protective behaved in a most curious manner, draining unevenly in streaks to give a rippling effect, and we could not get over this effect in any way by modifying times and temperatures of dipping. This uneven film failed very early in the test, no doubt at the thin portions. When the same petrolatum plus G.M.O. was applied from a solvent solution by cold dipping a thinner but uniform film was obtained which gave a better performance than the hot-dipped film of variable thickness. This explanation for the particular case does not, however, invalidate the main argument that performance can be affected by what happens during application.

W. R. STEET: There is one point in the application of petrolatum and inhibited petrolatum which should be noted, namely, when applied diluted in our field test, although the dip was carried out cold, the specimens, after the solvent had evaporated, were heated at 95° C in a horizontal position for 4 minutes so that application was in effect a hot one.

C. F. MCCUE: Since Mr Blane and I prepared our paper on American

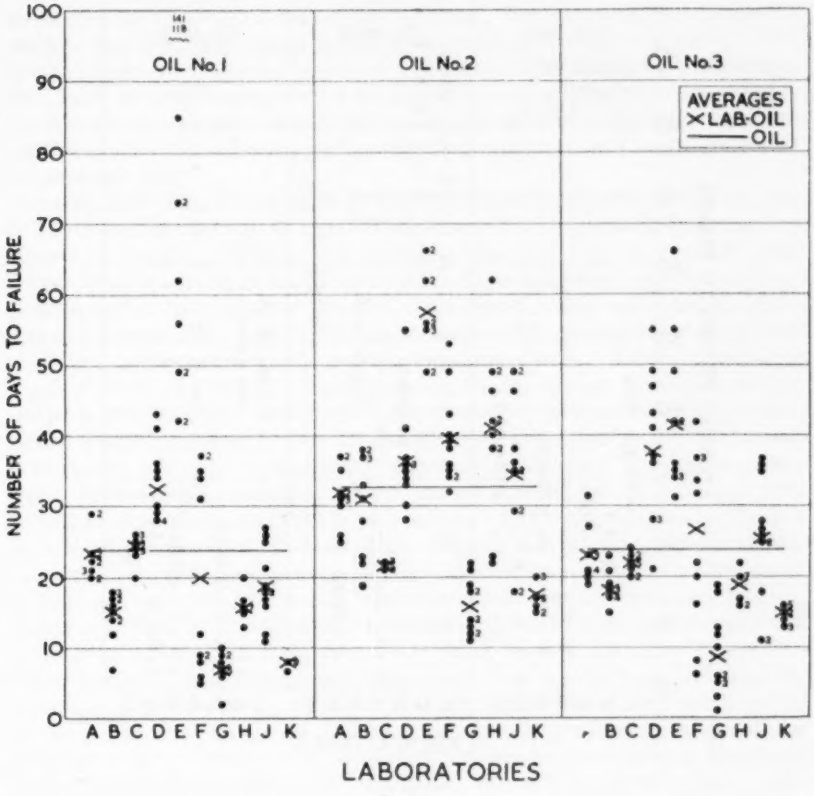


FIG. 3.

HUMIDITY CABINET STANDARDIZATION PROGRAMME. NUMBER OF DAYS TO FAILURE FOR EACH PANEL, ACCORDING TO OIL USED, IN EACH LABORATORY. (IN ONE RUN.)

practice I have received from the States a report published by the U.S. Navy Department entitled "A Statistical Study for Standardizing AD–H–31 Humidity Cabinets." The results of this study bear out, to some extent, some of the observations which we made in our paper.

The main part of the investigation entailed the assessment of three different oil-type protectives in the humidity cabinets of seventeen different laboratories. Ten of these laboratories tested the three oils simultaneously (*i.e.*, they loaded their humidity cabinets with eleven panels coated with

Oil No. 1, eleven with Oil No. 2, and eleven with Oil No. 3). The other seven laboratories tested the oils one at a time (*i.e.*, a complete run on thirty-three panels coated with Oil No. 1, followed by similar runs on Oils 2 and 3). The results obtained by these two methods are expressed graphically in Figs. 3 and 4 respectively.

In the original report these results are analysed in some detail, but for

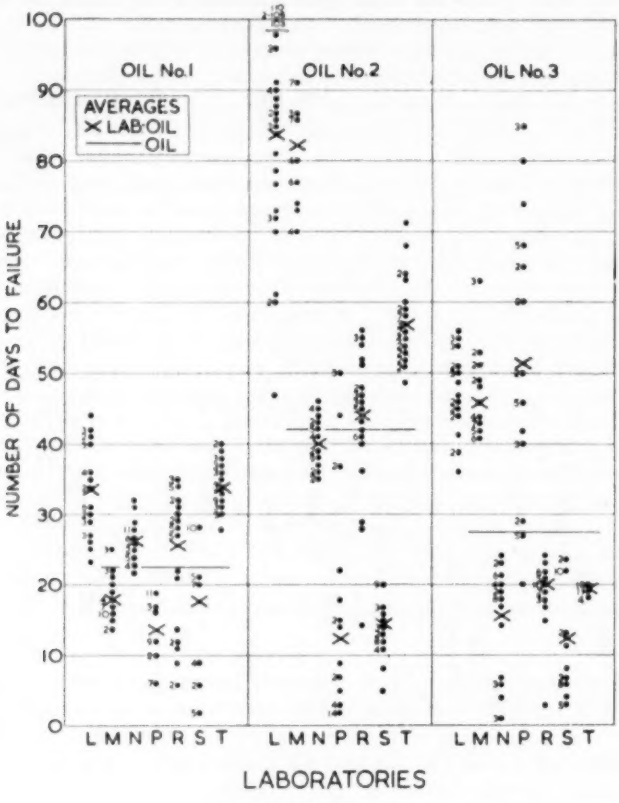


FIG. 4.

HUMIDITY CABINET STANDARDIZATION PROGRAMME. NUMBER OF DAYS TO FAILURE FOR EACH PANEL, ACCORDING TO OIL USED, IN EACH LABORATORY. (OILS TESTED SINGLY.)

our purpose an examination from two points of view will suffice : (i) The spread of results obtained when panels coated with the same oil are exposed in the same cabinet *at the same time*, and (ii) The differences between results obtained when the same oil is tested by different laboratories. Generally speaking, and with one or two notable exceptions, variations within any particular run were not too bad ; indeed in some cases they were extremely good. The reproducibility, on the other hand, was so poor that the various laboratories ranked the three oils in quite different orders of merit (compare,

for example, the results obtained by Laboratories M, P, and S). As pointed out in the report, " it is important to keep in mind that these *laboratory differences* may be either the differences to be expected among laboratories, or they may be the differences to be expected between *duplicate runs in the same laboratory*." In other words this lack of *reproducibility* may be due to a lack of *repeatability*.

I think that these results prove fairly conclusively that the AN–H–31 humidity cabinet as generally used is not suitable for assessing the relative merits of temporary corrosion preventives; furthermore, I venture to suggest that if such a survey as this were to be carried out on the " C.C.I." or any other humidity cabinet similar results would be obtained. Nevertheless, such cabinets have proved their worth over a large number of years for routine production-control, and their use for this purpose is likely to continue until it has been conclusively demonstrated that some other test is more reliable.

A technique which does seem to hold out some promise as an alternative to the humidity cabinet is the " Water-Drop " test, such as described by Hoar and Smith. As you will recall, in this test prepared panels were coated with a very thin film of protective deposited from a dilute solution, and then after the ageing of the film, ten drops of water were placed on the film of protective and inspected after 24 hours. The protective was assessed according to the number of drops showing signs of rust. Before considering the test in detail I should like, in passing, to express my doubts about the use of a very thin film obtained in this way—Dr Vernon has already questioned whether the sort of film obtained by deposition from a dilute solution is the same sort of film obtained by the usual methods of dipping or spraying. Then again, misleading results may be obtained by working with very thin films of certain types of protective. An example of this is afforded by our experience with D.T.D. 791. (This is the wax-thickened engine-preservative mentioned in the paper by Mardles and Mason; it consists of a suspension of wax in a volatile solvent containing a corrosion inhibitor, and it is applied to the cylinders of aircraft engines by spraying through the spark-plug holes.) As originally formulated it gave excellent protection when applied in thin films in the laboratory, but it sometimes failed under service conditions due to crazing of the film where it was very thick owing to the inherent difficulty of obtaining a perfectly uniform coating on the cylinder walls. Actually this particular problem has been largely overcome in the modified formulation D.T.D. 791A., but it does serve to show that results obtained on thin films may tend to be misleading. However, this sort of thing can be taken care of by carrying out ancillary tests to determine tendency to craze, etc.; and it does not necessarily invalidate the water-drop test.

Now a few words regarding the repeatability of this test. All the results quoted in Hoar's paper were obtained on two duplicate plates each coated with the same amount of protective and each bearing ten drops of water; agreement between two such panels was always remarkably good. But if the surface of each plate was perfectly uniform and if the coating was also uniform and all the drops were identical (as presumably was intended), then, surely, each individual plate with its ten drops of water can be regarded as ten separate experiments. A point I should like to

make here is that it is stated in the paper that " drops that are going to rust do so within the first few hours, any ensuing period up to several days resulting merely in the intensification of the rusting." In other words it is not a question of some drops rusting more rapidly than others—they either do or do not rust. Now, if a " go/no-go " test is carried out ten times on a sample of oil and it passes seven times and fails three times whereas a different oil passes five times and fails five times, I do not think it needs a statistician to say that not very much has been proved about the relative merits of the two oils. Yet, if my analysis of the problem is right, this is exactly what is being done in this test, and conclusions are being drawn from results such as these. Purely as a matter of interest I sent Table II to a statistician, and it appears that, statistically speaking, the addition of sulphonates made no significant difference in the case of the first, second, and fifth protectives, while in the case of the third and fourth the difference was just significant. I know the authors will object to all this on the very solid grounds that duplicate panels gave almost identical results. I think this can mean only one thing—there must be a flaw in my argument, but I am not sure where it is. I would like to suggest, however, that the fault lies in assuming that the coating is uniform (in passing I would very much like to ask the authors whether they have noticed any pattern in the distribution of rust drops, *e.g.*, was it the outermost or innermost drops which rusted—if there was a pattern this would indicate that the coating may be of variable thickness). Even if the thickness of the coating were consistent it still may not be a uniform coating; to put it in its simplest form it may be that we should regard it as having points of weakness—" holes " if you like—a good coating would not have many " holes," and a bad coat would have lots of " holes." The test is then reduced to taking pot-shots at these " holes " with ten drops of water. A straight oil has so many " holes " in it that a hit is scored every time; the addition of, say, lanolin closes most of the " holes," and the chances of scoring a hit are much reduced. I would very much like to hear from the authors as to whether this is the sort of mechanism they visualize for their test.

Dr Wyllie: Mr Pohl's paper discusses methods of expressing the degree of attack in corrosion tests. There are two conditions to express, incidence of attack and its intensity. One can readily describe the former by visual inspection, whereas the latter can be recorded as weight loss or by a series of notes and symbols based on visual inspection. The information is frequently set out in a series of tables. The point in which I am interested is the graphical method of presentation employed in Figs. 1 to 5 of Pohl's paper. In some work on sodium nitrite as a water-soluble inhibitor we employed visual inspection, and found that a whole range of different types of corrosion, varying from pitting to surface tarnishing, and involving several forms of corrosion products, could be obtained as one went from uninhibited to satisfactorily inhibited seawater. We expressed them by a graphical method, using a logarithmic scale, similar to that described by Pohl to record the area affected; we had, however, to write notes on the graphs to distinguish between different forms of attack. Mr Pohl does not employ other than marginal notes possibly since, as Dr Vernon said in his opening remarks, temporary protectives normally are

fully aerated, whereas the corrosion of specimens immersed in liquids is frequently governed by the available oxygen supply. I should like to ask whether Mr Pohl has obtained any results which could not be expressed graphically without use of notes on the graph itself?

V. W. DAVID: We found that tabulation of all the observations made in exposure tests gave rise to rather voluminous reports full of appendixes which did not add to their clarity. We subsequently adopted the graphical presentation of results as used in Mr Pohl's paper. The states of corrosion chosen were purely arbitrary, and their spacing along the y-axis was such that greater prominence was given to the initial stages of corrosion, since these are of relatively greater importance for the assessment of temporary protectives than are the later stages. Though logarithmic graph paper was not actually used in these experiments there is no reason why this should not be done.

The most frequent sequence of events was the development of a few pin points, then several pin points, then many pin points. These pin points then enlarged to small spots (diameter $\frac{1}{16}$ inch, visual estimation only) then to larger spots until eventually it was no longer possible or desired to make an accurate count. From this point onwards the states of corrosion were merely referred to as considerable, severe, and very severe. From time to time, however, it was found that a number of pin points which were close together would merge into small spots at an early stage of the breakdown of the film, and it was for this reason that we gave equal weight to, say, few small spots and many pin points in our graphs.

DR VERNON: Attention may usefully be called to a paper by F. A. Champion * in which recommendations were made for a standard scheme of recording the results of macroscopic and microscopic examination of corroded specimens. Another point is that the seriousness or otherwise of corrosion must necessarily be assessed in the light of the use to which the article is to be put. Thus, a degree of rusting (possibly small isolated spots) that would be permissible or insignificant for some purposes, might be fatal for others, *e.g.*, for certain fine gauges.

DR E. W. J. MARDLES: I think the graphical review of results is a real advance. It shows at a glance the performance of a number of protectives and is better than an appraisement number or a position in a group.

In the two papers of Pohl and Clarke and Longhurst, anyone looking at the diagrams realizes that he has a complete history of the corrosion tendency and protective properties, and that is most helpful. The logarithmic/time graph is useful where changes occur early. With some of the more permanent protectives the curve is concave to the time base, and probably then the ordinary time scale would be better, but with the temporary protectives the logarithmic time scale is an excellent idea, and I congratulate Mr Pohl on it.

R. J. BROWN: On reading the various papers, considerable disparity in

* *J. Inst. Metals*, 1943, **69**, 47.

the opinions of the various contributors is immediately apparent: this might at first suggest that none of the methods described is worthy of acceptance as standard procedure, although it emphasizes the necessity for such standards.

As a worker in the motor industry, the preservation of metals, particularly the ferrous variety, against corrosion is to me a pressing problem: I am somewhat diffident in suggesting that some of our troubles are due to the modern developments of the petroleum technologist, but let me hasten to add that although many of these developments have undesirable side effects, they are in the main essential to the performance of the modern motor vehicle. As examples I would give the addition to petrol of anti-knock compounds, whose use results in the formation of undesirable acidic compounds, and E.P. additives in axle oils which may dissociate under humid conditions during shipment, again with the formation of acidic compounds.

In the laboratories of the organization which I represent, temporary protectives are evaluated by means of outdoor weathering, humidity cabinet testing (the cycle of conditions being 8 hours at a temperature of 120° F and 100 per cent relative humidity, followed by 16 hours with temperature falling to 70-75° F in 3 to 4 hours, permitting gross condensation), and a salt fog test using 5 per cent solution of sodium chloride. The weatherometer has not been used for this purpose, as in the motor industry the protected parts are normally in the packaged state and the conditions existing in the weatherometer are unlikely to occur in transit.

Most of our investigations have been carried out with the soft-film, hard-film, and oil types of protectives: on three batches covering sixteen soft-film and fifteen hard-film protectives. Table I shows the agreement

TABLE I.

Agreement in Evaluation of Protectives by 5 per cent Salt-fog, Atmospheric Weathering, and Tropical Tests.

	Soft film, per cent.	Hard film, per cent.
Salt fog—atm.-tropical . .	44	27
Salt fog—atmospheric . .	25	27
Salt fog—tropical . . .	12½	27
No agreement . . .	6	7

obtained between the protective rating shown by the salt-spray test, atmospheric weathering, and the tropical test. Although these findings show only partial agreement, in general the indications have proved to be quite reliable by actual service tests. Reference is made in some of the papers to strippable coatings of the latex type, and of vapour-phase inhibitors: with regard to the former, mention is made of the addition of inhibitors and particularly sodium benzoate. The use of latex coatings was considered for the coating of motor spares in view of its relatively low cost as compared with other strippable coatings, but with ferrous materials it became immediately apparent that the presence of chemical agents in the

latex fostered corrosion, and that the additions of benzoate accelerated this corrosive tendency: experiments were carried out which indicated that sodium nitrite was a more suitable inhibitor, and Figs. 5 and 6 may be of interest.

Vapour-phase inhibitors, although still in their infancy, appear to offer one of the best solutions to certain corrosion troubles which cannot be prevented by normal methods. In a motor vehicle there are several assemblies which it is impossible to protect by normal means, such as brake and clutch assemblies when built either into the axle or the power unit, and for this purpose vapour-phase inhibitors appear to be most promising and have been adopted by us following severe tropical testing.

Dr T. P. Hoar: While giving tentative agreement to some of our ideas Dr Vernon thinks our thin films are too thin. The answer I think is this. The actual films we used were of the order of 0·02 to 0·06 inch thick, *i.e.*, much thinner than the film of a temporary protective should be, but unfortunately this sort of a film must always have very thin places. They are the weak links in the chain, and the test we devised was deliberately to test the weak links and not the strong parts. We feel that a temporary protective fails where it has been rubbed off or not applied properly, or at an edge. One notes that in many of the humidity cabinet tests the edges are deliberately neglected, although there must be edges in machined parts which these protectives are designed to protect. What we did was to test the weak links in general; that is the explanation and justification of the use of a very thin film.

Another point raised by Dr Vernon and also Mr McCue concerns the way in which the thin films are made. They are not really solvent-deposited, although they are put on from a solvent and that is allowed to evaporate, for the specimens are then taken to 90° C—the dipping temperature of the material—and kept at that for 15 min, so as to be comparable with the dipping procedure.

Dr Vernon also questions the use of distilled water drops. There was no precaution taken to exclude CO_2 from the laboratory air, and that may be a significant factor. We believe the best procedure would be to use pure distilled water and purified air, and to contaminate the air deliberately with measured amounts of carbon dioxide and sulphur dioxide; but such a procedure would involve, unfortunately, sacrifice or simplicity.

In answer to Dr Wyllie: we have not done tests on abraded steel used immediately; such tests would certainly have interest.

We at Cambridge have abandoned chlorinated solvents for some years, and now use either benzene or acetone for degreasing. But in the experiments reported, the carbon tetrachloride was distilled over quicklime and should be dry. The further point made by Mr Stroud regarding calcium chloride as a desiccant is of interest and should be noted by all corrosion workers.

I entirely agree with everything Mr Taylor has said about the unsatisfactory position of test methods generally. I think this symposium is showing that up very well.

Finally, with regard to Mr McCue's remarks about the possible statistical interpretation of these results, I fully agree that it would be very desirable

in all cases where there is any doubt of significance. It may not be out of place to recall that the Cambridge corrosion laboratory was, under U. R. Evans, among the first to use statistical methods in the analysis of corrosion results. The results we have reported in our paper are only a selection from a very large number of experiments which, although carried out in a rather hurried and imperfectly planned way, all pointed to the conclusions arrived at in the paper. Certainly in the more careful work possible under present conditions, both the planning and analysis of the tests by the drop-technique experiments on statistical principles would materially improve.

Evening Session.

Mr W. Pohl summarized the last four papers, and the discussion continued.

Dr T. P. Hoar: We are not at all clear exactly what we require, or are going to require, temporary protectives to do. Are they in fact to be usable for all conditions, indoors, in packages, in the tropics? Or are we content with a series of protectives, each with its specific application? It seems to me that economic and commercial considerations must be decisive in favour of a series of different materials, and that technical efficiency will also require several basic types.

It is quite clear in any case that a number of requirements must be met and that there must therefore be a number of different tests. For example, for humid conditions, tests based either on the humidity cabinet, or on the simple form of drop test such as Smith and I and also the American workers have suggested, seem reasonable. For contaminated industrial atmospheres, however, a test such as that of Preston and Stroud is indicated. For ordinary indoor store-shed atmospheres, I think no really satisfactory simple test has been proposed. For packaged exposure, again, we have no proper test: as Dr Vernon has shown, if dust is kept away from metal it may remain in its pristine state for many months, even years, without other protection; thus any accelerated test here will be difficult to devise. For simulating the conditions of a humid *marine* atmosphere, the salt-spray test comes into its own; but many people have shown that salt spray is most unreliable when used to indicate what will happen in a *non-salty* humid atmosphere. Finally, for protectives to be used under extreme conditions of low temperature where physical changes in the coatings may lead to mechanical failure, a test of such failure is perhaps necessary.

We thus have at least six possible storage conditions, for which we want six tests. The plea I make now is that, since we must have six tests, let us have them as simple as possible. That is one reason why I dislike the humidity cabinet and similar pieces of complicated and expensive apparatus. It seems to me that many people will require to carry out simple and cheap tests, and I want to emphasize very much my feeling that further work on the testing of protectives should aim at developing very simple techniques that anyone can reproduce in an ordinary laboratory not specially equipped.

I am impressed by the evidence that many protectives undergo changes with time, and I am glad that attempts are being made to devise tests to assess these changes, as in ageing tests taking account of the effects of exposure to oxygen and light. The changes that occur may be of crucial

importance in the behaviour of the protective, either destroying its value or, in certain cases, improving it; for example, the formation of organic acids in protectives may give rise to attack on various metals but, alternatively, in some protectives inhibiting substances may be formed. Thus one has to be very careful in assessing what oxygen uptake really means in terms of the value of the protective. But it is quite clear that such tests must continue to be made and to be developed.

I think Mr Taylor was quite right to bring out the rather unsatisfactory present position of testing methods. On the positive side, the Protectives Panel must be congratulated on initiating the large series of " field " tests on indoor corrosion conditions : it is only by such tests that we can get the proper data for the evaluation of laboratory or accelerated tests, present or future. But, at the risk of overstepping the bounds of our present discussion, I should like to say once again that many of us feel that testing procedures for protectives have now, apart from desirable simplification of techniques, been made almost as good as can be expected *in the present state of fundamental knowledge*. It seems to me that we require much more fundamental knowledge of the way in which a temporary protective works before we can much improve our testing procedures. It is only by fundamental research that we shall discover what can be achieved by temporary protectives other than the mere mechanical exclusion of water. This, a relatively easy matter for the smooth parts of an article, which can be thickly and uniformly coated, may be difficult or impossible at the corners and edges, where drainage and chafing lead to thin, porous coatings; we require to know how to make protectives that will take care of these conditions, and also how best to test them. Among other things requiring research, I would mention particularly the interaction of the protective molecules, especially of any active polar groups therein, with the oxide films on metal surfaces; the transport of oxygen and water through the layer of protective; and the displacement of protective molecules from the oxide-film surface by water or other potentially corrosive substance. It is quite clear that far too little is known about these matters, and it is very desirable that fundamental research should pursue them. With the knowledge gained, as well as finding better protectives, we shall be able to devise new and more effective testing methods.

Dr E. W. J. Mardles : Fundamental knowledge on adhesion would be helpful. There is a paragraph in each paper relating to the need for good wetting and good adhesion. Many of the difficulties caused by thinning and draining, dust particles, presence of water, etc., involve the adhesion problem. Hoar and Smith have given a good deal of attention to this problem, showing that a non-polar mineral jelly is improved as a protective by the addition of an amphipathic substance.

Similarly, Clark and Longhurst mention that " Plain mineral oils were poor protectives, rust developing within a few hours, but oleic acid additions to the oil, up to the maximum content tested, markedly retarded rusting."

This is apparently against the current theory which assumes organic acids in an oil are liable to increase corrosion. I think the explanation lies in the fact that there is increased adhesion. From lubrication research it is known that polar molecules form a strong boundary layer which probably

can displace water in the same way that a film of lanolin can displace water. The surface activity of medicinal liquid paraffin is increased by adding oleic acid. If a film is displaced by abrasion or dust or grit, a surface-active film creeps back again, but an ordinary non-polar material remains inert, in the same way that an indifferent lubricant is pushed out of the bearing or pivot by the applied load, but a good lubricant tends to creep back again. It would appear that fundamental research on surface adhesion is important not only to lubrication but also to the subject of the protective action of films against corrosion.

Little is known on the subject of "tackiness," what it is, or how to measure it, but it is a subject of importance in the testing of temporary protectives.

R. J. Brown: Doped fuels produce all sorts of undesirable compounds in the combustion spaces: as the evacuant for the lead compounds, aviation spirit contains ethylene dibromide, and the fuel itself is of high quality, whereas in the motor industry a worse condition has to be met as regards protection against corrosion due to the use of ethylene dichloride as the evacuant in a low-grade fuel. For some reason chlorine compounds appear to us to be much more corrosive than the bromide compounds produced by combustion of aviation spirit.

Reference has been made to tests for evaluating engine protectives, using hydrobromic acid as the corrosive medium: we have used this method of evaluation and related methods, and while they are partly successful, we have nevertheless found it necessary to treat complete engines with the inhibitor and then subject them to an extended humidity test in order to obtain worthwhile information on the effectiveness of the various preparations suggested for this type of preservation. Such a test shows beyond doubt that certain of the modern engine-preservative oils containing vapour-phase compounds are greatly superior to the conventional preservative fluids. [Evidence of this was provided by a series of slides in colour.]

S. D. Steele: The user's point of view is that he must have protection for a part in transit so that it arrives at site in a satisfactory condition. By the use of this protection the part may be made of a much less expensive material than would be required if no protection were available.

There is a great deal known of the resistance offered by various steels to corrosive media, and many results obtained in test have repeatedly been proved in practice. When it comes to testing protective coatings, then, let us use, say, a series of steels whose corrosion-resisting properties are well known, and let half of each specimen be painted with the protective coating under examination. Now submit all specimens at one time to the corrosive conditions to be resisted. By such methods a considerable amount of useful information may be gained, together with a very practical basis upon which to compare the performance of different coatings. Furthermore, means are made available for examining the protection afforded by a coating relative to the material painted, a point which is perhaps rather frequently overlooked. If desired, curves may be drawn of the degree of corrosion *prevented* versus time, which although negative

in character, are nevertheless every bit as informative as the more conventional type of graphical record. Data are obtained, of course, from the unprotected portions of the specimens.

Results so obtained are remarkably reproducible. In the absence of any definite or standard test for the examination of protective coatings the foregoing suggestions may perhaps represent a point of view which some of those present may care to consider.

Dr R. Sperling : A number of these accelerated corrosion tests incorporate the use of salt spray or salt solution, the assumption being that because unprotected steel is more rapidly attacked by salt solution than by water, the same applies to steel coated with temporary protectives. I have, however, come across cases where the protection afforded by temporary protectives is much better when the corrosion conditions are severe than when they are mild, for example, quite good against salt solution, but very poor against distilled water. There have been instances, too, where anti-corrosive oils have protected steel when the surface was sand-blasted and susceptible to rapid rusting, and yet have not protected steel having a highly polished surface which tended to rust more slowly.

Dr J. Mason : I felt a little confused, after reading these papers, about temporary protectives. There seems to be a conflict of view. Is it " temporary " as regards removal, or " temporary " as regards protection ? I only hope for the sake of some of the protectives I have examined that it is temporary in regard to protection !

With regard to corrosion in the sphere of petroleum products, there are three types—the oxygen–water type, the organic acidity type, and the corrosive sulphur type. With regard to the solubilities of oxygen and water, these diminish as you go from the gasolines to the lubricating oils, and the effects are in that same order. There is less corrosion with a lubricating oil than with a gasoline, but a lubricating oil is not used if a good protective is wanted, partly because it will oxidize.

Inquiries at Harefield have arisen from the eternal problem of the corrosion of bearings. This seems to be a bogey which raises its head from time to time, but fortunately progress is being made. The inhibited greases are very much better, but they are not capable of lasting indefinitely. For the best temporary protectives one turns to mineral jelly and a microcrystalline petroleum wax—and it was a disappointment to me when Hoar and Smith, in their very interesting paper, mentioned that the higher-melting-point mineral jellies did not respond so well to compounding with petroleum sulphonate.

On the oxidation question we have also had trouble with hydraulic fluids. I venture to think that the staining we have had with a certain temporary protective may be due to this oxidation phenomenon. In a temporary protective there should be nothing oxidizable and no derivative of any acid whatever, organic or inorganic. If polar groups are required to make the protective stick, the make-up must be such that there shall be no risk of acidic corrosion.

With regard to Mr Brown's contribution on engine corrosion, there have been only two reports of trouble regarding D.T.D. 587. In hot climates the

coat was not viscous enough to stay there, so the material was replaced by something else. The second case was amusing. It failed because it was not there! The number of barrels of protective used was insufficient, and the problem was solved by looking up the store record of barrels and counting the number of engines.

H. HOLLIS: Dr Mason has said that he considers that a temporary protective ought to be completely free from oxidizable material. I would certainly hesitate to say that Norma Hoffman bomb tests will not provide valuable information about the corrosivity of an oxidized petroleum film, but it would be unwise at this stage to consider the test as more than tentative from this point of view.

Long before temporary corrosion preventives were ever thought of the more durable paint films were (and for that matter still are) formulated from drying oils which dry largely by oxidation. Many temporary corrosion preventives which have stood the test of time have, moreover, been based on lanolin, a material which I imagine will absorb oxygen rapidly if tested in the Norma Hoffman bomb. I do feel therefore that there is a grave danger in paying too much attention to the oxidation stability of the material. The criterion surely should be, "How does the material function in relation to the metal substrate once it has become oxidized?" In this connexion I suggest that a more logical approach to the problem would be to expose panels coated with the preservative to an oxidizing atmosphere prior to, or during, the performance testing, when the development of any corrosive oxidation products would become readily apparent.

V. W. DAVID: Regarding the last point made by Mr Hollis, it is known that certain types of protective coatings harden on exposure over long periods due to oxidation. The resulting film is then frequently insoluble in solvents, so that the rust-preventive composition in question cannot be said to meet the requirements of a temporary protective. It would seem, therefore, that an ageing test is important and might precede, as a kind of sorting test, the exposure tests Mr Hollis has in mind.

DR MASON: I do not think that Mr Hollis's views and ours are necessarily incompatible. In fact, I think we have tried to convey that impression in our paper. I think that a paint forms a coat on the outside which becomes impermeable to things like oxygen, and water, before any damaging organic acidity can be developed. This is something which could be put to the test.

With regard to Mr Brown's remarks, he did not mention the use of lead-free fuel. In inhibiting engines it is an essential feature to run them for a while on lead-free fuel. Mr Brown commented that it was extremely difficult to get lead-free fuel from normal sources or permission to use it.

K. R. GARRETT: Tests for examining temporary protectives, particularly the humidity cabinet and salt-spray methods, were carried out on mild steel panels. Components to be protected often consisted of two dissimilar metals in contact. A ball-bearing may be taken as an example. Thus, in actual practice we get the electrolytic effect of two dissimilar

metals in contact, this being particularly pronounced in a humid atmosphere. Under certain conditions copper acts as a catalyst in the oxidation of greases, etc., so that when copper alloys are present the behaviour of the protective is not the same as that indicated by the tests carried out on mild steel panels. Many types of equipment sent abroad contain a number of dissimilar metals, often in contact. The electrolytic effects and the particular behaviour of copper may combine to cause breakdown of the protective film.

Dr T. P. Hoar: I think Mr Hollis and Dr Mason are not really disagreeing. The oxygen uptake that occurs in the drying of paints is utilized in the oxidation-polymerization type of reaction, not in the production of acid. Furthermore, the production of certain long-chain acids, such as stearic or oleic, from original non-polar materials may possibly be beneficial, for these acids can sometimes be inhibiting, not corrosive.

F. A. Paine: With regard to packaged products, which Dr Hoar said might not need so much protection as the rest, I would like to point out that packaged goods are often knocked about during transport, and as a result the protective layer may be damaged or rubbed off. In a large number of instances the metal article is in contact with paper or board. If the protective layer is incomplete for any reason and the paper or board contains chloride, which is quite likely, corrosion can occur at the points of contact.

R. A. Fraser: Mr Pohl in his paper quoted three figures for the amount of film left on the surface of the specimens after 24 hours draining and four weeks draining. These were suspended in a vertical position. Immediately following, in the section on humidity cabinets, mention was made of exposure tests on specimens inclined at ten degrees to the horizontal. Clark and Longhurst describe exposure tests made at 45 degrees. If draining was still taking place from vertical plates after four weeks' exposure it seems to me that the angle at which the specimens are exposed will make considerable difference to the thickness of the layer. I think we should carefully consider the standardization of the angle at which the specimens are supported in these corrosion tests.

W. Pohl: On the point of drainage, I would like to ask the authors if they have any definite evidence whether, in fact, it was drainage or loss by evaporation. It is extraordinary how much can be lost by evaporation from thin films of light oils, and I wonder if, in this case, it was not drainage at all but evaporation.

J. I. Hill (read by P. G. Humphrey): The transport industry, like many others, is confronted with problems concerning the testing and usage of temporary protectives; they include the protection of finely machined and polished parts whilst in store, and also, as a special case, the protection of similar parts in transit. On the heavy engineering side there is an interest in the protection of exposed moving parts, often highly stressed, such as the motion rods of locomotives, which must be subjected to regular and frequent inspection.

In the past some experimental work has been carried out on the protection of ball- and roller-bearings: on this point it is interesting to note that as long ago as 1910 a prominent firm of ball-bearing manufacturers called attention to the fact that the grinding process left the surfaces of steel balls and races very susceptible to external chemical and electrolytic influences. Such effect had been observed in stored bearings protected with thin layers of greases of the petroleum-jelly type, and the firm recommended the use of a proprietary grease, and stressed the importance of the bearing being fully packed with such protective; the type of grease was not defined, but it was possibly of the lime-soap type, and the observation was probably the first to indicate reliance for protection being closely associated with thick films. A good many years ago tests were made at one of the laboratories using the water-drop technique on bearings protected with different types of composition, and in some cases wrapped in oiled paper with an outer pasteboard box: the results broadly went to confirm the observations by the manufacturers referred to above.

The locomotive industry has been interested in securing satisfactory temporary protection of polished steel rods working under high stress and under conditions where they could frequently come into contact with water and other atmospheric corroding factors; it was undesirable to cover such parts with permanent paint films, since such a course would preclude regular and frequent inspection for incipient flaws due to corrosion fatigue, and possibly other causes. As at that time there was no known laboratory or accelerated test on which reliance could be placed to correlate the results with effective service, no alternative was open but to carry out test observations under practical working conditions: the broad results were that moderately hard films containing treated lanolin were reasonably successful, though a disturbing factor in the case of locomotives was the effect on the protective of lubricating oil, which always found access to the covering. Lanolin preparations containing metallic dust failed to establish any clear superiority over the non-metallic type. Temporary protectives of the water-soluble type acting by surface inhibition, such as solutions of nitrites and chromates, were considered and tested; but having regard to the working conditions they were not expected to be serviceable, and experience showed that to be in fact true. It is appreciated that the observations given above are simple practical trials of materials of which some knowledge of their protective properties existed and which appeared the best available.

Recently, in connexion with investigations on the use of protectives for locomotive connecting and coupling rods, field tests were carried out on lines very similar to those on which the recent field tests by the Panel were based. Mild steel panels, prepared by shot-blasting, were used, and a range of temporary protectives brush-applied. The panels were exposed vertically, not under cover, so they withstood the rigours of the weather. The range of materials tested included most of the well-known types, including some officially specified. It was found that some of the panels were completely protected up to as long as eight months' outdoor exposure, whilst quite a number gave a reasonable degree of protection for five months, though the standard of judgement was less critical than those recently adopted by the Panel. Broad conclusions were that the protection

offered by some of these formulations was surprisingly high, the paste preparations (thick layers), in general, being superior to those thinned out with a volatile solvent. Pigmenting was, on the whole, shown to be an advantage, in some cases marked, and in this connexion oxide of iron additions proved to be advantageous : some of the formulations containing chromates did not give such satisfactory results, but as the base materials were not the same it was not possible to make any close comparison between the effects of different types of pigment.

A direction of investigation applied by one organization for the testing of hard and semi-permanent films of the paint type, utilized measurements of electrical properties : one of the early tests was the Digby apparatus employing a plate of steel prepared as nearly as possible in standard fashion and coated on both sides with a paint film. It was necessary to protect the edge with insulated tape covered with a thick hard varnish. The plate was submerged in an electrolyte, which could be varied in character, with solid graphite plates positioned on either side : periodical measurements of electric potential were made, and by correlating the changes in potential with time it was possible to work out a " protection factor " which, in the case of certain types of paint, bore some relationship to their service life as proved by field tests. Later work on the measurement of electrical properties by the D.S.I.R. has stressed the relation of area of corrosion with electrical capacity, and represents a further and probably more favourable development; in a communication to *Nature* 1947, the authors suggest that their method had possible alternative application to the study of other types of protective coating, and even of films produced by corrosion inhibitors.

All industries interested in temporary protectives suffer from the lack of established correlation between accelerated or laboratory tests and service life as judged by field tests or practical experience. There is little service experience with which to compare laboratory test results, and it might be that the reverse is equally true. American experience, too, seems to indicate that tests with humidity cabinets have no value for pre-detecting protection against outdoor exposure, although there is some reliable correlation with exposure under the more violent conditions of tropical exposure. It is also recorded that humidity cabinet cycle tests, involving a short period of condensation conditions, followed by exposure under non-condensing conditions, but at elevated temperatures and at 100 per cent relative humidity, correlated fairly well with sheltered outdoor exposure.

It is perhaps not unfair to regard the position up to as late as 1949, as somewhat disappointing and unpromising, particularly bearing in mind the difficulties introduced by such obscure factors as the influence of " finish " on the problems of protection. It might be thought that with field tests using fairly large panels, the final finish of the surface of the steel secured by hand rubbing with abrasives, either alone or attached to paper, was not sufficiently standardized to ensure that strict control necessary in the problem under consideration with its many difficult and obscure factors; the permeability to moisture or other corroding forces of films, either fluid or in the form of jellies or greases, may call for close and more elaborate investigation by entirely new technique.

It is suggested that there is need for closer collaboration between the

research and scientific organizations, both of manufacturers and users, in order that developments in formulation by makers can go hand in hand with the wider range of testing, both laboratory and field, available with the two interests working together.

During such joint work attention could be focused on indirect factors which might subsequently prove useful on formulation based simply on practical experience and observation, and one suggestion that can be offered is as follows. It has long been known that the journals and axles of wagons used solely for the purpose of carrying lime are maintained, without special attention, in a highly polished and satisfactorily unworn condition over many years of life: it is common observation that such wagons bear permanent deposits of fine lime dust on the axlebox so that it could be anticipated that some of it would find ingress into the lubricator and thence to the lubricant. In their early days, if not at the moment, the lubricant used was probably what was known as the old railway wagon grease, consisting of an emulsion of mineral oil, fats or fatty oil, and soap sometimes produced by hot saponification in the process of manufacture: the grease was left slightly alkaline, probably within a limited range of pH value and contained about 50 per cent of water. The mere fact that such type of grease, containing such a high content of water, has been successfully used for many years as a lubricant and has maintained the journals in a polished and highly protected condition may be of interest in the present-day problems, particularly when we remember that such wagons stand a great deal longer than they are in motion. It is suggested that one line of development in formulation might be to utilize the simple rust-inhibitory properties of alkalis within a pH range to be determined by test, such type being applied in a sufficient thickness of film to give protection against attenuation of the film by outside sources to a thickness which would in practice prove inadequate.

W. J. Haire: I have been particularly interested in the references to tests involving spotting with water, because a simple test of this type was found useful some time ago in work carried out by the Scientific Research Department of the former L.M.S. Railway with the object of assessing the comparative suitability of a wide selection of commercial temporary protectives to prevent rusting of ferrous articles during transit by rail. In this test, which was developed by S. C. Britton, duplicate bright steel panels, $4\frac{1}{2}$ inches $\times$ 2 inches, were coated on both sides by brushing, and allowed to drain and dry for at least 24 hours. They were then laid on a smooth level bed of damp sand in a tank, and 30 drops of rainwater were placed on each specimen. The tank was covered, and the progressive development of rust in the drops was observed at intervals. The damp sand, while providing a level surface and a reservoir of moisture to retard evaporation of the drops, also served to induce condensation on the under-faces of the specimens, so that inspection of the upper and lower surfaces gave indications of comparative resistance to stagnant water and to condensed moisture respectively. Grading of the various materials was usually possible after a week.

Other properties of coatings which were considered relevant to the purpose in view and were investigated included:—

(1) resistance to direct rainfall (for this, panels were exposed in the open at 60° to the horizontal, the undersides giving an additional indication of the effect of condensation);
(2) liability to damage by rubbing, scratching, or squeezing;
(3) retention of dirt;
(4) ease of removal.

All materials were graded in respect of each of these various properties separately, and, in general, no attempt was made to assess all-round merit (which no single test can measure), since the importance attaching to any particular property varies according to the type of article to be protected, the method of packing, and so on.

Accelerated weathering techniques, as used for testing paint films, were considered and rejected, largely because they introduced a heating effect towards which the various materials showed widely differing susceptibilities. Moreover, acceleration proved to be unnecessary; long-term protection was not sought, and the outdoor-exposure test permitted adequate grading after a short period of the order of 14 days.

T. Henry Turner: From the Atmospheric Corrosion Sub-Committee (B.I.S.R.A.) point of view environment must be given the greatest attention. I recently suggested that representatives of three sections of the D.S.I.R. meet in Birmingham, namely:—

(1) the atmospheric pollution testing team of the Fuel Research Station, Greenwich,
(2) the British Iron and Steel Research Association corrosion research Committee,
(3) the Atmospheric Corrosion Research Section of the Chemical Research Laboratory, Teddington,

to see whether by suitable collaboration we can ascertain the corrosivity of the atmospheres encountered in various parts of the country. This was done, and we are now planning that next year we shall co-ordinate these three groups of interested research workers. So that when, for example, we expose a sulphur candle at a D.S.I.R. atmospheric-pollution testing station, we shall also expose corrosivity test pieces of, for example, a copper-bearing steel and zinc.

In one of the papers a question is asked regarding mild steel. The Corrosion Committee has been carrying out corrosion tests for many years past in mild steel in various parts of the world, sub-arctic and tropical as well as European, and we have recently come to the conclusion that a better test material would be a standardized copper-bearing steel rather than the ingot iron used in Dr Hudson's earlier tests. That is something to be borne in mind.

Whether testing of temporary protectives can be linked up with the atmosphere is a point worth consideration, because there is such a thing as micro-meteorology; for in any street the atmosphere is not the same on one side as the other. The same applies to any town. In London, the atmosphere southwest, at say Teddington, is almost as clean as possible, whereas northeast, at say Stratford, it is much polluted. Such variations

must be borne in mind. They are often due to the prevailing wind; in this case from the southwest.

We have corrosivity tests abroad also, and the arctic and the tropic atmospheres seem nothing like as severe in attacking metal as the sulphur-dioxide-laden atmospheres of the industrial districts of Great Britain. Speaking in terms of centuries this is a new phenomena.

Looking down from York Minster at the smoke over the city, it is clear that extensive coal burning has corroded the stone of the cathedral through the emission of sulphur fumes. There is a quarter of a million pounds to be spent on that building because of the sulphur put into the atmosphere in the last hundred years. A graph for the yearly output of coal will show where the sulphur fumes are coming from. The excessive sulphur dioxide content of the atmosphere in Britain is not found so widely spread in any other civilized country.

None of the cities on the Continent of Europe have anything like the same amount of corrosion due to sulphur dioxide. Yorkshire alone is putting half a million tons of sulphur dioxide into the air each year. That is something which we must take into consideration when planning corrosion testing in Britain.

The Corrosion Committee has encountered quite different conditions in other countries when studying metal corrosion. Metal at Khartoum, for example, did not need paint because the dry atmosphere and sand kept specimens clean and bright. Iron is preserved in the Thames river mud; the bed of the Thames has proved to be an excellent corrosion protective; to the benefit of archæologists. Norwegian peat bogs have done the same. Swords and other metal parts have been found perfectly preserved in a bog, which proves the importance of actual environment. Sheffield with its polluted atmosphere has a museum in which you can see brightly polished old scissors. They are exposed behind glass, and that fact stresses Dr Vernon's classic work which showed that particles of dust settling on the surface give rise to corrosion. Those scissors, some of them a hundred years old, still show bright metal because they are kept behind glass in a town where the normal atmosphere is highly corrosive : micro-meteorology is clearly important.

The Atmospheric Pollution Sub-Committee is only one of a group, of which another is the Corrosion Testing Sub-Committee.

Some of the corrosion troubles we encounter are the result of transport moisture and abrasion. For example, it is important that sheet steel for the electrical industry should be free of rust. Much money is spent getting steel into thin sheet form which can then be easily ruined with rust. Temporary protection of such steel is needed for transport and storage.

Other large uses have not been mentioned, for most of the speakers have been dealing with clean metal. There is, for example, the corrosion of boiler-plant. The art of water treatment has been so improved in the last ten years that a modern boiler will not corrode at all while in continuous service. It will corrode much more when not in use than when in use, and there is a real need at the moment for a good temporary protective for the inside of a boiler, which will, of course, have relatively rough surfaces.

Constructional steels are in a similar category, and civil engineers have

need of effective and cheap temporary corrosion protectives. The steel-makers want to send out their steel in good condition, and there is no point in putting paint on it. Mill scale is a temporary protective, but unfortunately it is so brittle that it cracks, and then is worse than having the steel free from all scale.

Some of the features noticed in testing ordinary, or rather longer time, protective coatings have been also noted by yourselves. For instance, hot galvanized wire feels "blobby"; if the finger is run along it, it is not uniform, and it fails by corrosion where the coating is thinnest. If the wire is electro-galvanized with a thinner but uniform coat of zinc, the protection is uniform and so of more value.

Looking through the papers my feeling is that I should like to go through them again to see what the temporary protectives are to be used against; for variations in conditions of corrosive environment and metal-surface condition will require the specifying of different types of temporary protectives. I do not see in these papers a list of the common uses. It is always easy to be wise after the event, but these papers now put us in a new position. I suggest that we should classify the conditions of service and nature of surface for which the temporary protectives are to be used, and then design tests to suit such conditions and the uses.

According to the metals and alloys we have in mind, some will be thinking of aircraft, some of razor blades, some of laid-up steam-boilers, and so on. Each one thinking of temporary protectives for a limited field. I hope we shall be able to design tests to match the many alloys and the many fields of use, without too much complication.

Dr Clayton: On the matter of correlation with the B.I.S.R.A. committee, we have through the Protectives Panel made an approach. We do not clash: although a representative of the B.I.S.R.A. Corrosion Laboratory could not be on our panel, it has been agreed to keep in as close touch as possible. As soon as the shelter tests are completed we propose to send the results to the B.I.S.R.A. Laboratory so that they get full consideration and are commented on.

Dr S. G. Clarke: One form of salt-spray test has given promising results in the work described in the paper. Nevertheless, there are some misconceptions about salt-spray testing, and I would like to make a few remarks to help clear them up. The use of salt-spray has in the past acquired a rather dubious reputation as the test has tended to be regarded as somewhat variable and not to represent practical conditions.

As regards variability I agree that the older uncontrolled tests were very suspect. It is surprising that it is only in the last few years that salt-spray tests have been studied scientifically, and it was not until 1948 that work was published on separate lines in Britain and America, in which the actual severity of corrosion was determined by exposing bare steel to the spray and determining the weight of steel that had corroded. The results gave a series of shocks to preconceived notions, but we now know something about the variations and how to control them. There are now two distinct forms of test. The continuous salt-fog type of test standardized by the A.S.T.M. obtains reproducibility by a built installation with elaborate controls, but

there are factors which still remain critical, such as the atomizer and the air pressure, also the specimen has to be in the chamber at a certain angle because the corrosion depends on the amount of precipitation on the specimen. The Armaments Research Establishment salt-droplet method, standardized for certain purposes in the U.K. and used in the present work, seeks to avoid many of the difficulties by simply putting on droplets to a certain degree on the test surface by a hand-spray and then covering over the specimens to preserve a still humid atmosphere around them. Temperature control would be necessary only outside the usual air-temperature range.

Slides were shown illustrating these methods. One slide showed water droplets resting on the test-surface, which simulates also what might happen in, say, a humidity-cabinet test. Previous speakers in discussing the humidity cabinet queried the purity of the moisture which condenses and the consequent effect on the results. This leads to the thought that the deliberate use of an electrolyte as the liquid might even things out and give better reproducibility; that is where a certain amount of salt in the liquid may help.

As regards the alleged artificiality of the salt-spray test, it is questionable if this is actually a drawback. What we seem to be measuring in these tests is the resistance of the protective coating to permeation by an aqueous electrolyte and atmospheric oxygen, which together cause visible corrosion of the steel surface. The permeation may be at weak spots or by diffusion. Failure of the coating under practical condition, except through mechanical damage or erosion by rain, is probably also due to this permeation by electrolyte, but the time required will vary enormously with the severity of the conditions. This may be an over-simplification of the case, but in a controlled laboratory test the conditions should be relatively constant, and if the resistance to permeation is related to protective quality of the coating there seems no reason why a test of the salt-spray type should not be capable of giving a useful comparison between these coatings. This view conflicts with Dr Hoar's opinion that the salt-spray test should be used only for testing to meet marine conditions. Perhaps he had in mind differences in rate of corrosion of certain metals in salt-spray and other tests, but with oil or grease coatings on steel it is the occurrence of corrosion rather than its rate that gives the useful first indication of failure of the coating.

W. Pohl: Dr Clark's persuasive comments have almost convinced me that the salt-spray test is a good one, but I cannot help feeling that there is something which he has not told us. A previous speaker mentioned the very large differences between different laboratories when using this simple test. That was a very real experience. In recent laboratory work in which this salt-spray test was used as a specification test, the two laboratories differed so that the sample passed the specification according to the one and failed according to the other. I feel that Mr Clark has not given us the clue as to why we get that sort of difference between results.

N. Clarke: I think Mr Pohl's remarks are connected with a series of tests on a particular type of protective, conducted in the Chemical Inspec-

tion and Shell laboratories, respectively. We have been investigating the tests, and I feel that these differences are probably due to lack of observation of the conditions; notably the maintenance of the humidity during the period of the test. We think we have solved them and we hope shortly to ask Mr Pohl to co-operate with us in some further series of tests.

B. S. Wilson: The previous speaker has commented on the reduction of corrosion by the addition of organic acid as a constituent of a protective medium. The power of an organic acid to initiate corrosion in the absence of air or other oxidizing agent is negligible.

Dr J. Mason subsequently wrote: We have had corrosive effects with metals and oxidized greases and metals and castor-based hydraulic fluids, which seem more related to organic acidity than to anything else. As we have stated in our paper, however, a good deal of further work could be done on the subject.

Dr R. Sperling: An important factor in the protection of steel with oil solutions of petroleum sulphonates is the leaching out of the petroleum sulphonates by deposited water. This depends on the relative solubilities of the petroleum sulphonates in water and oil. Petroleum sulphonates are much more soluble in water than in salt solutions, and this may explain differences in the results obtained with humidity cabinets and with salt-spray tests.

The sodium salts of oil-soluble petroleum sulphonic acids are relatively less soluble in predominantly paraffinic oils than in predominantly aromatic oils. This may account for the poor performance recorded by Hoar and Smith for solutions of sodium petroleum sulphonates in H.M.P. jelly which is relatively highly paraffinic. The reduced solubility of the sodium petroleum sulphonates in the paraffinic H.M.P. jelly facilitates their transfer to the aqueous phase. It has been demonstrated that aqueous solutions of sodium petroleum sulphonates exert no inhibitive effect on the corrosion of metals. Similarly, films of calcium petroleum sulphonates deposited on metal surfaces have no marked effect.

F. A. Greenwood: May I be permitted to point to a weak link in testing technique? In assessing the degree of corrosion, for instance, are a few spots the equivalent of a few pin points, and so on? It does seem that there is a need to concentrate some work on finding out how to assess corrosion. It seems to me that one possible way would be to use photo-electric cells and measure the light scattering or absorption of the test pieces.

Dr Clayton: There has been a suggestion to use very thin steel strips so that the corrosion goes through very quickly, and light could then be passed through the strip.

Vote of Thanks.

The Chairman, in closing the meeting, thanked all who had contributed to the discussion for the interesting material they had presented. He

continued : Although it is evident that the discussion could continue for some time, it has been nicely balanced in that comments have been made on most of the important aspects of the testing of temporary corrosion preventives, right through from the preparation of the test panels to the assessment of the results. Those who have not had time to speak, or who have any further thoughts, are invited to send in written comments so that the printed record will be as complete as possible. The Protectives Panel in particular will study the discussion very carefully and if necessary modify its programme.

E. A. Evans : I am sure you will agree with me that Dr Clayton has infused life into the subject. He has given the symposium originality and vitality and has made it illuminating.

I have been very impressed by the background and the different facets of this important subject. From what I have heard during this symposium it is clear that inhibitors have a useful place, even if only for a time. Many, I think, will now realize how very few compounds there are which will check corrosion of metals. Those of us who are working on the synthesis of these compounds are too well aware of the difficulty of finding compounds which can be used with hydrocarbons for that purpose.

I am extremely grateful to Dr Clayton for organizing and guiding this symposium, but we can go further. Dr Clayton has been the chairman of the Panel which has been doing this very important work, and from the views which we have gathered today and the papers which have been presented it is perfectly clear that he has done a magnificent job—Dr Clayton, on behalf of the Institute of Petroleum, I offer you our grateful thanks. And to Mr Steet, who has helped Dr Clayton I would also like to convey our thanks.

Then there are the authors of the papers. They have had no mean task. They have produced excellent papers which will go down in history.

Dr Clayton : It is very kind of you to make these remarks, Mr President. I would like to emphasize how much of the work has been done by Mr Steet. He has been most enthusiastic.

Communications.

Dr J. C. Hudson and Miss C. Coe : Our general impression from reading these papers is that the whole subject of laboratory testing of temporary protectives would be advanced and correlation between the results of different investigations would be greatly facilitated if more attention were paid to the standardization of certain points of testing procedure. For example :

1. Unless there is good reason to the contrary the size and method of preparation of the blank test panels should be standardized. P.B.S. 1391 : 1947 * calls for tests on rectangular steel panels 6 × 4 inches cut

* Provisional British Standard 1931 : 1947. Performance test for Protective Schemes embracing Stoving Paints used in the protection of Light-gauge Steel and Wrought Iron against Corrosion. British Standards Institution.

from 20 s.w.g. steel sheet of a defined quality. It would be an advantage if, so far as possible, all tests were made on this size and type of specimen.

2. A standard salt-spray solution should be adopted. Here again P.B.S. 1391 : 1947 lays down a standard namely :—

Sodium chloride, NaCl	23·0 g	per litre of solution
Sodium sulphate, $Na_2SO_4,10H_2O$ . .	8·9 g	
Magnesium chloride, $MgCl_2,6H_2O$ . .	9.8 g	
Calcium chloride (anhydrous), $CaCl_2$.	1·2 g	

It is noteworthy that Mr Clinton uses a solution of a different composition not only for his continuous salt-spray tests but also for his intermittent salt-spray test. Now although no one would claim that the solution laid down in P.B.S. 1391 : 1947 was necessarily better than any similar solution, it is clearly to the general advantage that all workers should use the same solution, and it would be just as well to adopt the P.B.S. 1391 : 1947 solution for the purpose. Incidentally, the use by Mr Clinton of a 1 per cent sodium chloride solution for his intermittent salt-spray test seems ill-advised to us because we regard the presence of the magnesium salts as desirable in order to increase the deliquescence of the residue resulting from the partial evaporation of the spray. Nor do we understand why he stored his specimens horizontally instead of vertically as laid down in the specification.

3. The criteria of failure should be standardized. In the present series of papers these vary from one investigation to another. We appreciate that this is a difficult problem. Perhaps a scale of degrees of rusting, such as has been adopted by B.I.S.R.A.—Breakdown of Protective Painting Schemes on Steel,* might prove useful.

It also seems to us that the method of testing should be related to the service conditions. It is clear, for instance, that the conditions of laboratory testing needed to reproduce the performance of a protective scheme exposed to the bright light of a marine atmosphere unpolluted by smoke, may be radically different from those needed to predict its behaviour in a heavily polluted industrial atmosphere where the degree of solar radiation is low. For this reason, at the present juncture, we would advocate that workers in this field should continue to investigate a wide variety of methods of testing, leaving the decision as to which of them should be finally adopted until more experience has accumulated.

We may add that P.B.S. 1391 : 1947 is in process of revision and that the Methods of Testing (Corrosion) Sub-Committee of B.I.S.R.A., who are responsible for advising the British Standards Institution in this matter, would be glad to receive any comments on this specification.

S. E. Bowrey : *Control of Condensation in Humidity Cabinets.* Continuous or streaming condensation with its washing-off effect is generally to be avoided in humidity-cabinet tests intended to simulate storage under more moderate conditions.

* Breakdown of Paint Films on Steel Surfaces—Standard Degrees of Rusting—to be obtained from the B.I.S.R.A. Corrosion Laboratories, 514 Bristol Road, Birmingham, 29.

The aim is to secure close control of condensation, and this is usually attempted by providing an atmosphere of high humidity, the temperature of which varies in cycles to produce alternate misting and drying-off. The method is open to criticism. Condensation begins with the rise of air temperature above that of the specimen. The amount of condensed moisture will be such that its latent heat of condensation equals the heat absorbed by the specimen, less the heat received by conduction and radiation. After thermal equilibrium has been reached it may be presumed that the amount of moisture on the specimen remains constant unless influenced by radiation to or from surfaces where equilibrium is attained later.

The wet period ends not with the beginning of the cool-air cycle, but only with final evaporation of the moisture. In theory the heat held by the specimen should be just sufficient to drive it off, but the rate of evaporation will diminish steadily, and the period for which the specimen remains wet will encroach upon the cool-air cycle by a time affected greatly by adventitious factors such as heat loss by conduction and radiation.

The writer, therefore, developed an apparatus in which the specimens were directly water-cooled and, instead of cycling the air temperature, the temperature of the specimen was alternately raised and lowered. The actual arrangement consisted of a series of segmental specimens soldered to a circular backing plate, which in turn was backed by a water space of small capacity. The water passing rapidly through this space was supplied at intervals of a few minutes alternately from two tanks, one warmer and one cooler than the humid air in the cabinet. The period of condensation, as well as the amount, could thus be very closely controlled, and any conditions achieved from slight misting to copious streaming.

An indication of the extent to which the timing of the cycle affects results was afforded by the fact that the few seconds required for the water space to change temperature were sufficient to induce a difference of behaviour between the specimen nearest the water inlet and the one nearest the outlet. This was eliminated by inserting a paddle in the water space. There is inconvenience in soldering specimens to a backing plate, but it is suggested that it could be overcome by means of tubular specimens gripped between nipples for internal water circulation. Tubular specimens could, incidentally, be surfaced at least as easily as flat ones.

Tests for Effectiveness of Temporary Protectives in Passivating Existing Corrosion. Although, in the majority of applications, temporary protectives are applied to surfaces which are entirely free from corrosion, cases not infrequently arise where previous corrosion has taken place and the surface has to be treated either in its condition as found or after a mechanical treatment which may, or may not, entirely remove the active centres of corrosion. If any given application involves the possible presence of such active centres, then it is desirable either to make use of some passivating pre-treatment or to use a protective which, itself, will passivate the surface as completely as possible.

Obviously those protectives which are completely insoluble in water will not have the desired effect, and the coating formed by them will be disrupted as corrosion proceeds underneath.

Last year a complete set of main-engine gearing taken from a ship which

was being broken up was stored for replacement use in a sister ship. It was rusty when received, and the need for stopping the corrosion before storing was evident. The method adopted was to clean away the old rust and apply a coat of sodium nitrite paste. Previous experience showed that within 10 to 20 days this would arrest corrosion running $\frac{1}{16}$ inch deep, and that under reasonably dry storage conditions the paste would give protection for from six to twelve months. Since in this case the storage period might extend into years, the nitrite paste was left on for a month and then replaced with lanolin.

It is possible, though not certain, that adequate passivation and long-term protection would have been secured by a single application of a petroleum sulphonate-type protective. It is suggested that some means of assessing the behaviour of a protective coating when applied to surfaces not entirely free from corrosion pits might be of practical interest.

KAUFF VAN OOSTERWIJK: The investigation of rust preventives carried out by Koninklijke/Shell-Laboratorium, Amsterdam, on behalf of the Protectives Panel of the Institute of Petroleum provides an opportunity to study more closely the suitability of the laboratory experiments involved for the evaluation of temporary corrosion preventives.

Below a comparison is made between the results of the field test (winter 1949–50, outdoor shed exposure on the roof of the laboratory) and those obtained in the following two laboratory experiments:

Humidity cabinet test—100 *per cent R.H. Temperature* 49° ± 1° C (70 *days, according to specification* AN–H–31).
Salt spray test—20 *per cent* NaCl *solution. Temperature* 35° C (1–4 *days*).

The eleven rust preventives examined were numbered from 1 to 11 according to their decreasing merits in the three different tests and thus compared. The correlation coefficient between field test and laboratory tests was calculated from these numbers.

The following observations can be made concerning the separate evaluation in the three tests:—

I. *Field Test.*

The evaluation is based mainly on the time required for the formation of five rust spots per surface, irrespective of edge rusting, and subsequently on the further progress of rust formation.

Rust formation was judged visually from panels covered with preventive. This method of evaluation gives rise to the following difficulties—

(1) What was to be the standard size of a rust spot? Our experiments showed that, particularly at the beginning of the exposure, rust spots were very small, often only perceptible when the panel was in a certain position and in sunlight.

(2) In the case of edge rusting, the absence of a marked boundary between the edges and the surface under consideration causes confusion as regards the number of rust spots.

(3) In the case of dark rust preventives it is impossible to observe and to follow rust formation, while in the case of translucent layers rust formation may actually have proceeded further than was perceptible on the panel covered with preventive.

II. *Humidity Cabinet Test.*

In the case of (*a*) (see table) the appearance was inspected visually after a test period of ten days, after degreasing; in the case of (*b*) evaluation took place according to the decrease in weight of the derusted panel considered over the whole test period.

In our opinion it is impossible in the humidity cabinet test to observe accurately the rust formation on a panel covered with preventive. The sharp edges of the panels are first attacked, as a result of which rust is

Decreasing Order of Merit of Eleven Rust Preventives (I.P. Preventives Panel).

Field test.	Humidity cabinet test.		Salt-spray test.
	(*a*).	(*b*).	
C.S.1033D	C.S.1033D	C.S.1033D	Petrolatum
C.S.1033B	Petrolatum + G.M.O.	Petrolatum + G.M.O.	Petrolatum thinned
Petrolatum	Petrolatum + G.M.O. thinned	Petrolatum + G.M.O. thinned	Petrolatum + G.M.O.
Petrolatum thinned	Petrolatum	Petrolatum	C.S.1033D
C.S.1033D, thinned *	Petrolatum thinned	Petrolatum thinned	Petrolatum + G.M.O. thinned
D.T.D.121D	D.T.D.121D	C.S.1033B	C.S.1033B
Petrolatum + G.M.O. thinned	C.S.1033B	C.S.1033D thinned	C.S.1663F ?
Petrolatum + G.M.O.	D.T.D.121D thinned	D.T.D.121D	C.S.1033D thinned
D.T.D.121D thinned	C.S.1663F	C.S.1663F	D.T.D.121D
C.S.1663F (probable)	C.S.1033D thinned	D.T.D.121D thinned	D.T.D.121D thinned
C.S.1663C	C.S.1663C	C.S.1663C	C.S.1663C

* Severe edge rusting.

The lines indicate separations between clearly distinguishable groups.

Order of Merit of Laboratory Tests in Comparison with Field Test.

	Field test.	Humidity cabinet test.		Salt-spray test.
		(*a*).	(*b*).	
C.S.1033D	1	1	1	4
C.S.1033B	2	7	6	6
Petrolatum	3	4	4	1
Petrolatum thinned	4	5	5	2
C.S.1033D thinned	5	10	7	8
D.T.D.121D	6	6	8	9
Petrolatum + G.M.O. thinned	7	3	3	5
Petrolatum + G.M.O.	8	2	2	3
D.T.D.121D thinned	9	8	10	10
C.S.1663F	10	9	9	7
C.S.1663C	11	11	11	11
Correlation coefficient	—	0·52	0·64	0·59

suspended in the condensed drops of water; these drops with rust drip along the surface of the panel under test and hamper close observation. It is better to take a given time as test time and to decrease and evaluate the panel after that period.

III. *Salt-spray Test.*

The loss in weight of the derusted panel was taken as basis for evaluation.

The attack in salt spray, starting at edge and hole, with streaks running down the panel, is on the whole rather severe, so that it is almost impossible to check the exact beginning of rust formation and to observe the formation of rust spots.

The above comparison shows that there is hardly any correlation between the two laboratory tests and the field test. The conclusion must be drawn that the two laboratory tests, which show a somewhat better correlation (correlation coefficient 0·75), give a rough separation into good and poor products, but that they are unsuitable for a fine differentiation of products of divergent types, as used for this investigation.

Remark Concerning the Application of Preventives.

Unless special precautions are taken, application of corrosion preventives on a large panel by immersion results in an uneven layer, thinner at the top than at the bottom, with an even thicker dripping edge at the lower end. The weight of the preventive on the panel is, therefore, not a measure of the layer thickness. As the value of a preventive is mainly determined by the layer thickness, it would not appear permissible to relate some sequence or other directly to the weights applied.

Replies to the Discussion.

Dr S. G. Clarke and Dr E. E. Longhurst: We appreciate the comments of Mr Fraser and Mr Pohl on the results of loss of oil from specimens on exposure, and the consequent effect on protective value. Their only purpose in quoting the figures is to draw attention to this point, which appears previously not to have been given due weight in testing the protective value of oils. In the case of sheltered exposure, the mechanism of the loss of oil is not clear, that is how far it is accounted for by drainage and evaporation separately. The panels exposed in a sloping position were, in addition, open to washing by rain, as the underneath of the panel was found to have retained more oil than the upper side. We think, in general, that in comparing protectives, the film thickness actually present must be taken into account. In so far as the angle of the specimen may affect the drainage and consequent film thickness, and no doubt for other reasons, it might well be standardized, but as is done in certain tests described in the paper, actual determination of the coating remaining on the surface at the conclusion of the corrosion test is desirable, in the case of oil films, to give a good basis for the assessment of the result. Comparison of oils at the film thickness they are likely to reach after prolonged drainage also appears desirable.

Mr Taylor remarked on the discordance between the results of outdoor

and salt-spray tests on oils. This appears clearly to be due to a factor entering into one test and not the other, viz., washing off by rain, and this exception to the general concordance between salt-spray test and outdoor exposure is thus thought to be of little importance, especially as oil protectives are likely to find little use for withstanding outdoor conditions. It was, however, shown in one experiment recorded in the paper that under mild conditions in the absence of much rain, the outdoor result is similar to what would have been obtained in the salt-spray test. We are not aware of any marked lack of reproducibility of our salt-spray test in other work, and wonder whether the answer to Mr Taylor in this respect is not the same as given by Mr N. Clarke to Mr. Pohl on a similar point.

Dr Hoar made the remarkable statement that no less than six different kinds of test are needed to cover the various conditions of use of the protectives. We suppose that he means tests of a research type to investigate the performance of the coatings under different conditions. It is possible that the results will not necessarily indicate the need for such a large number of inspection or performance tests for practical use in connexion with specifications. Indeed, the correlation between certain individual tests given in papers in this symposium offers a reasonable prospect that for practical purposes the number of tests might be cut down to one or two.

R. St. J. Preston and E. G. Stroud : We would like to thank Mr Taylor for his references to our method of testing temporary protectives. We wondered at the time of writing whether a correlation coefficient as high as 0·92 was not too good to be true, having regard to the large range of protectives tested and the short duration of our tests. We now rather fear they may have been, for Mr Taylor has made an interesting point which had been overlooked, viz., the fact that protective coatings D.T.D.121D. dilute and C.S.1663C particularly show greater losses of steel after test than the blanks. We can offer no sound explanation for this; there is undoubtedly a possibility of experimental error which although it could not account for the whole difference, may lessen it. It was not possible to carry out duplicate tests at the time, the fact that four tests were done on each type of protective being considered to show to some extent the repeatability of the test.

Clearly the anomalous results require further investigation, and in the absence of such, it is only possible to suggest a possible cause, by deduction from the information obtained from the test series. All the " anomalous " protectives contain less than 15 per cent lanolin, which may be considered more reactive than the mineral oils and thinners. Compound formation between the alcohols in lanolin and sulphur dioxide may take place to give an acid body, thus accumulating the gas and increasing the rate of corrosion compared with blank steel. It is of interest to note that Clarke and Longhurst found that protection with lanolin exposed outdoors fell off rather suddenly, and Jakeman (*Special Report No.* 12 *Engineering Research D.S.I.R.* 1929) says " satisfactory mixtures are made by taking equal parts by weight of lanolin and white spirit." None of his tests included concentrations below 29 per cent, and most " straight " solution contained over 40 per cent.

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Oilfield Exploration and Exploitation.

Geology.

1594. Introduction to petrophysics of reservoir rocks. G. E. Archie. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 943–61.—The paper suggests the term "petrophysics" as most appropriate for the study of the physics of particular rock types, particularly for the detection and evaluation of hydrocarbon deposits.

A tentative petrophysical system is presented which revolves mainly around pore-size distribution.

The author concludes that the lithologic description of rocks is important as well as mineral composition. The lithologic description should be broadened to express pore-size distribution. E., N. T.

1595. Aerial photogrammetry as applied to the petroleum industry. L. A. Woodward. *Petrol. Tech.*, Jan. 1950, **2** (1), 9–15.—A brief outline of the use of aerial photographs for preparing topographical and geological maps, with diagrams and photographs as illustrations.

Photography has been carried out at heights from 800 to 32,000 ft, and for 1 : 20,000 negatives with an 8¼-in lens the mean height above ground should be about 13,750 ft, with photographs taken at intervals of about 1 mile. An area of 368 sq miles was photographed, and the prints with 5212 elevations were delivered in some 2½ months. A composite mosaic with structural contours was made on a scale of 1 in : 4000 ft. A topographic map prepared photogrammatically seldom costs more than 60% of a comparable map made by plane-tabling, and is usually more detailed. G. D. H.

1596. Modern mapping methods. G. Fitzgerald. *World Oil*, Mar. 1950, **130** (4), 69.—During and after the war there has been much progress in developing and perfecting mapping methods. New surveying techniques and equipment are briefly described. These include location finding by shoran, electronic elevation-measuring instruments, the Electric Survey Net Adjuster, which eliminates laborious mathematical computations, and plotting instruments for use in aerial mapping. C. A. F.

1597. Reserves are up. C. J. Deegan. *Oil Gas J.*, 16.3.50, **48** (45), 56.—On January 1, 1950, U.S.A. proved reserves were estimated as follows: crude oil 24,649,000,000 brl, natural-gas liquids 3,729,000,000 brl, natural gas 180,381,000,000,000,000 cu. ft.

Each figure was greater than the corresponding estimate for January 1, 1949.

Tables give the reserve figures by states, with the 1949 production and the reserves added in 1949 by new discoveries, and by extensions and revisions. G. D. H.

1598. Lakeview pool, Midway-Sunset field. W. P. Sims and W. G. Frailing. *Petrol. Tech.*, Jan. 1950, **1** (2), *A.I.M.M.E. Tech. Paper No.* 2779, 7–18.—The Lakeview pool, Kern County, California, was opened in 1910 by a gusher which ran wild and is estimated to have produced 8,250,000 brl of oil in 544 days, but full development began in 1935, and all but five of the 112 wells were drilled before 1941. At the end of 1949, the cumulative output was about 41,000,000 brl (55·3% of the tank oil originally in place) and about a third of the wells were still producing, the output being about 2000 b.d. Production is from Pliocene and Upper Miocene beds on a northeast-dipping monocline. The main sand (Lakeview) wedges out up-dip and fingers down-dip. The edgewater is not mobile, although there has been local coning. Scanty data on sand characteristics indicate an average porosity of 33·1% and an average permeability of 3655 mD. The max productive sand thickness is over 150 ft.

Since the depletion of the bulk of the gas energy by the gusher the pool has operated

under gravity drive. This is favoured by the relatively high dip, good permeability, and fluid properties. The oil recovery since the beginning of 1942 has been relatively steady at about 53,000 brl/ft drop in fluid level, and it is estimated that ultimately the recovery will be 63·3% of the oil in place. G. D. H.

1599. Niagaran reefs in Illinois and their relation to oil accumulation. H. A. Lowenstam. *Oil Gas J.*, 2.3.50, **48** (43), 48.—In Illinois Devonian and Mississippian production has been obtained over Niagaran reefs (Sandoval, Bartelso, McKinley). Tonti and Patoka may be underlain by similar reefs. At Marine most of the oil is from the reef, and substantial production from the reef has been obtained at McKinley, and Bartelso, and possibly at Sandoval. To date Niagaran production has been from large reefs near the reef front. The front is probably sinuous. In the northeast in the La Salle anticlinal belt " dead " oil has been found in the Niagaran reef in wells, and asphalt at outcrop in the Chicago area. Northwest of the area of greatest reef development there is a belt with fair prospects of reef production, though the reefs may be smaller and truncated by erosion. Deeply eroded reefs with poor oil possibilities may be present in central Illinois.

The Moccasin Springs formation when present thins over reefs. Fingers of fossil debris extend some distance to the lee of the reef. Structural highs occur in beds over the reefs; these are generally more or less parallel with the reef front, and they may differ from the regional trends.

Maps show reef distribution and the main subdivisions of areas with prospective reef production. There are brief statements on a number of wells which have indicated reef occurrences. G. D. H.

1600. 1000-bbl a day well drilled by Carter. Anon. *Petrol. Engr*, May 1950, **22** (5), B-80.—Mamie-Strahm 2, near Sabetha in Nemaha County, Kansas, produced 1000 b.d. from Viola limestone at 3572 ft. 1 Strahm, 350 yd southwest of No. 2, is producing 25 b.d. C. A. F.

1601. Second pool for Forest City basin? C. J. Deegan. *Oil Gas J.*, 13.4.50, **48** (49), 141.—In northern Lyon County, Kansas, 1 Cornwell has met the Hunton at 2950 ft, and in a drillstem test at 2952–2967 ft recovered 1000 ft of 30–34° oil. A test of the Mississippian at 2480–2511 ft recovered only mud. The Hunton pinches out against the Ozark plateau, and the well must be near this feature. The well is based on surface structure, and is in the Forest City basin, east of the Nemaha granite ridge. 17 miles to the north on the Davis Ranch the Viola has given a nice little field, and the Viola remains to be tested in 1 Cornwell. G. D. H.

1602. Gulf completes Denton well. Anon. *Petrol. Engr*, May 1950, **22** (5), B-80.—L. R. Chamberlain 1 has been completed as the second Devonian producer in the Denton field, Lea County, New Mexico. The well flowed 1092 b.d. of 41·6° oil from the Devonian from 11,501 to 11,513 ft G.O.R. was 889 : 1. C. A. F.

1603. Well flows 650 bbl in 24 hr. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-80.—1 Oklahoma State D, in Beckham County, Oklahoma, flowed 650 b.d. of high-gravity oil with 950,000 cu. ft. gas Plugged-back depth is 9970 ft. . C. A. F.

1604. The Ardmore Basin—geology and oil possibilities. E. T. Peterson. *World Oil*, Mar. 1950, **130** (4), 57.—The Ardmore Basin is in southeastern Carter County, Oklahoma. Although oil has been produced in Carter County for nearly fifty years, the potential reserve of the basin remains great. Little development has taken place, due to the great depth of favourable horizons which are productive nearer the surface in adjacent areas.

The basin is elliptical, and at its northwestern limits there are a series of structural anticlines on which are the Hewitt, Healdton, Graham, and Sholem Alechem pools. To the southeast, the basin is covered by a Cretaceous mantle. Formations present range from Pre-cambrian to Permian, and subsurface structure and stratigraphy are complex. The pools in the basin may be classified as : anticlines (*e.g.*, Sholem Alechem), unconformity traps (*e.g.*, Wildcat Jim), stratigraphical traps (*e.g.*, Overbrook), ensing sands (*e.g.*, Brock), and compound (*e.g.*, Healdton). Stratigraphical traps are

commonly found at shallow depths where dipping beds are faulted, chiefly on anticlines. Unconformity traps are normally found at shallow depths where flat-lying Pennsylvanian beds cover the post-Hexbar unconformity. Lensing is found where beds have been elongated and thinned by folding, or where environmental conditions have favoured lenticular sand deposition. Such conditions are frequent in the Pennsylvanian, Viola, and Simpson (Ordovician).

Immediate development of the basin is unlikely, but it remains a potential reserve for development when deeper drilling becomes necessary. C. A. F.

1605. Sinclair well flows 777 bbl in 15 hr. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-80.—2 Stephens, in the Southwest Antioch pool, Garvin County, Oklahoma, flowed 777 brl of 43·6° oil in 15 hr. Production is from the Gibson between 6761–6781 ft and 6799–6820 ft. C. A. F.

1606. Well flows 560 bbl in 11 hr. Anon. *Petrol. Engr*, May 1950, **22** (5), B-80.—5 Immohotichey, in Garvin County, Oklahoma, flowed 560 brl in 11 hr. Plugged-back depth was 6953 ft. C. A. F.

1607. Oklahoma test interests geologists. C. J. Deegan. *Oil Gas J.*, 16.3.50, **48** (45), 137.—In Washita County, Oklahoma, on the north flank of the Wichita mountains, a wildcat has recovered 28·2° oil in a drillstem test of the Hoxbar granite wash at 5305–5355 ft, some 2500 ft below the top of the granite wash. The well is on a seismograph structure and a little northwest of a well (Rocky gas field) which found gas and distillate in the Springer in 1946. Cores in the Springer showed dips of 85°. The Rocky well had dips of 20–65° in the Springer. G. D. H.

1608. Rocky Mountain outlook picks up. C. J. Deegan. *Oil Gas J.*, 9.2.50, **48** (44), 125.—In the southwest Powder River basin north of Salt Creek the Sussex, East Sussex, North Meadow Creek, and South Meadow Creek fields produce from the Sussex, Shannon, Second Wall Creek, or Lakota sands. The last three fields are spread over about 4 miles, and may be local highs on a regional high running north–south. The present productive area is two to three locations wide.

In the Glenrock townsite area the second well has produced from the Dakota, having found the Muddy, which produced in the discovery well, shaled out. G. D. H.

1609. Completes Wintergarden well. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-84.—2 McKnight, in Dinnit County, Texas, flowed 5,100,000 cu. ft. gas/day on open flow. Total depth was 3310 ft. C. A. F.

1610. New reef area? Anon. *Oil Gas J.*, 16.3.50, **48** (45), 52.—A wildcat in Kent County, Texas, has topped the Canyon reef at 4116 ft subsea, some 384 ft above the water-table for the Scurry County Canyon reef fields. Cores bled oil. The wildcat is 17 miles north of the Scurry–Kent county line. G. D. H.

1611. New reef pool. Anon. *Oil Gas J.*, 2.3.50, **48** (43), 28.—5 miles southeast of the Cogdell area, Kent County, Texas, and 3 miles north of North Snyder a drillstem test in a wildcat which tapped the Canyon reef at 6787 ft has indicated the probability of commercial production. G. D. H.

1612. New reef oil in Kent County 15 miles north. C. J. Deegan. *Oil Gas J.*, 6.4.50, **48** (48), 119.—17 miles north of the Cogdell area 1 Young in central Kent County, Texas, has flowed 33 brl/hr of 39·5° oil on a ¾-in choke from perforations at 6480–6520 ft, after acidizing. A mile southwest of Clairemont 1-A Jones has given 5–7 brl/hr of 48·3° oil from 6740 to 6752 ft in a drillstem test. The pay may be the Strawn. This well is 6 miles east and 4 miles south of the 1 Young well. G. D. H.

1613. West Texas reefs jump west and south. C. J. Deegan. *Oil Gas J.*, 30.3.50, **48** (47), 174.—A well on the southern edge of Borden County, half-way between the Vealmoor field in the west and the 1 Reinecke well, topped the Canyon reef at 7410 ft,

and on test this flowed oil and gas at about 15 brl/hr. The bottom-hole flowing pressure was 2600 p.s.i.

1 Solomon, in northwest Mitchell County, after acidization has flowed 40–50 brl/hr from perforations at 7448–7468 ft in the Pennsylvanian. G. D. H.

1614. Extend Scurry County reef. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-86.—Reinecke 1, in Bordern County, Texas, initially flowed 1140 brl in 19 hr, confirming a 5½-mile southwest extension of the Scurry County Canyon reef. C. A. F.

1615. Skelly wells flow 100 bbl an hour. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-80.—Three wells completed in Scurry County, Texas, had the following characteristics: 1 Harral flowed 2708 b.d., 2 Harral flowed 801 brl in 6 hr, and 3 Harral flowed 600 brl in 6 hr. Total depth of wells was about 6800 ft. C. A. F.

1616. Scurry County north end gap narrowed. C. J. Deegan. *Oil Gas J.*, 2.3.50, **48** (43), 103.—A drillstem test at 6787–6808 ft in 1 O.R. Buffaloe flowed oil at about 15 brl/hr. This well is north of North Snyder. Diamond "M" has been extended ¾ mile to the southeast. On the southwest side of reef trend in Borden County 1 Von Roeder was completed with 185 b.d. of 38° oil. 1 Reinecke 5 miles to the southwest of 1 Von Roeder, has a potential of 1487 b.d. of 46° oil. A 2-mile northwest extension of the Vealmoor Canyon reef field is indicated in southwest Borden County. G. D. H.

1617. Small-scale structures and other features of Navajo sandstone, northern part of San Rafael Swell, Utah. G. A. Kiersch. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 923–42.—The Navajo sandstone is a thick deposit of uniform quartz sand of Middle (?) Jurassic age which has been considered as a classic example of aeolian deposition.

Studies of small-scale structures throughout the northern part of the San Rafael Swell have been analysed, and the author presents a petrographic analysis of the sandstone and a generalized geologic columnar section.

An intraformational distorted zone of alternating crumpled and undisturbed cross-bedded units is described and an origin suggested.

That the dominant manner of deposition for the Navajo sands throughout the northern part of the San Rafael Swell was by southerly winds seems conclusive from the character of its cross-laminations. Short periods of aqueous deposition were common during accumulation of parts of the lower section of the formation, as evidenced by the thin, essentially horizontal, cross-bedded, argillaceous, and calcareous members with their distinctive cross-lamination patterns. E. N. T.

1618. Lower-middle Mississippian of southeastern West Virginia. D. Wells. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 882–922.—The lower-middle Mississippian formation (of lower Greenbrier age) of southeastern West Virginia is composed of the Hillsdale and Denmar formations which were deposited in a transgressing sea along the flank of a linear, southwestward plunging mio-geosyncline.

The Hillsdale formation is thick-bedded, nearly black, fine- to medium-grained, cherty limestone which is recognizable to northwestern Pocahontas County and disappears westward as a wedge in south–central West Virginia. The Denmar formation succeeding it contrasts lithologically in having less chert, lighter colour, and more sandy material. E. N. T.

1619. Pure test below 13,000 ft. Anon. *Petrol. Engr*, May 1950, **22** (5), B-80.—A test at Badwater, Natrona County, Wyoming, is drilling below 13,790 ft. It is planned to reach 16,000 ft, to Frontier sands, which are productive at West Poison Spider. C. A. F.

1620. Approach to the origin of oil. W. K. Link. *Oil Gas J.*, 16.3.50, **48** (45), 88.—Rocks close to and associated with oilfields generally do not look petroliferous, while black shales that look petroliferous, and from which something looking like oil can be extracted, are generally not associated with oilfields. The shales near oil pools have little or nothing that is physically or chemically like a residue left in oil formation.

Oil formation is believed to involve the accumulation of organic matter in sediments,

its transformation into hydrocarbons and subsequent maturing to oil. In approaching the problem via recent sediments it is necessary to consider that bacteria, radioactivity, heat, pressure, time, and catalysts may be involved in the processes. In the Gulf Coast area conditions of deposition, temperature, etc., seem to be almost the same as in the Tertiary. It is not known whether gas, heavy hydrocarbons, light hydrocarbons, or waxes are formed first.

A systematic foot-by-foot analysis of the sediments from the youngest downwards should throw light on this problem if oil begins to form early in the history of the sediments. Samples should come from the bottom of the Gulf of Mexico, wells being drilled offshore and in the swamps (with sampling and coring as sterile as possible).

The idea that oil took a long time to form may be a fallacy. G. D. H.

1621. Offshore activity. L. S. McCaslin. *Oil Gas J.*, 30.3.50, **48** (47), 62.—In Block 24 of the South Pass area, Plaquemines Parish, a Shell wildcat has tested 375 b.d. of 30·7° oil from 11,203 to 11,299 ft, with a flowing tubing pressure of 2800 p.s.i.

Two Magnolia wildcats in the Eugene Island area off Iberia and St Mary parishes show signs of being productive.

Currently sixteen wells are drilling in the Gulf of Mexico, six being wildcats. A table lists the offshore wells with their completion dates and initial outputs.

G. D. H.

1622. Canadian Gulf completes third Stettler producer. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-80.—Ellis 13, 100 miles northwest of Calgary, Alberta, was completed in the D_3 at 5377 ft. 150 ft pay were found, including 50 ft in the D_3. C. A. F.

1623. Oil search in Alaska. Anon. *Oil Gas J.*, 30.3.50, **48** (47), 74.—Seven tests are planned for U.S. Naval Petroleum Reserve No. 4 in 1950, four being on previously untested structures. Seven geological, one gravity-meter, and five seismic parties will be in the field.

In 1949 twelve core-holes were drilled to depths of 900–1400 ft, near seeps on the Simpson Peninsula. One blew out and caught fire. Wells were drilled to 2900 ft, 7020 ft, and 11,400 ft (unfinished). All had showings of oil and gas. G. D. H.

1624. German reserves up. Anon. *Oil Gas J.*, 13.4.50, **48** (49), 73.—Proved and probable oil reserves in western Germany are placed at about 260,000,000 brl. This is an 80% increase over the previous year's figure. 73% of the reserves are in the Emsland region, and the amount has been nearly doubled in a year, mainly due to the Suderbruch discovery. The Hanover district has 22·4% of the total reserves, Hamburg and Schleswig-Holstein 4·4%. The rest is in Baden. G. D. H.

1625. The Etzel salt dome. F. Breyer. *Erdöl. u Kohle*, 1950, **3** (4), 153–62.—The Etzel salt dome in E. Friesland was first discovered by gravity survey in 1931, and further information was obtained by subsequent refraction and reflection seismic surveys as well as from twenty-six deep wells. The geological history of the structure is discussed, and it is concluded that the salt movement was not related to any of the main orogenetic phases in the region and that the formation of the salt dome was concluded before the Dogger β-transgression took place. Later movements in the Cretaceous and Tertiary did not lead to additional salt penetration.

There are asphaltic sands in the Upper Eocene on the S.E. flank of the salt dome, but not in sufficient quantity to warrant mining. The oilfield is on the northwest flank, and production is from a limestone breccia at the base of the Cornbrash. The components of this breccia are very similar petrographically to the Posidonia Shales found in borings near the salt dome, and it is possible that the oil is genetically related to the bitumen content of those shales. S. E. C.

1626. Deep wildcat projected in Russian zone of Germany. Anon. *World Oil*, Apr. 1950, **130** (5), 244.—Reports indicate that a deep test is to be made in the abandoned Bebra-Lohra potash mine in Nordhausen district.

575,000 brl were produced from the Volkenroda potash mine from 1930 to 1938. Subsequent tests in the area were unsuccessful. C. A. F.

1627. U.S.S.R. concentrates operations in Matzen area of Austria. Anon. *World Oil*, Mar. 1950, **130** (4), 222.—The latest well in the Matzen area flowed more than 5000 b.d. on completion. Early wells averaged 700 b.d. C. A. F.

1628. Investigation of the possibility of the present-day formation of methane in gas- and oil-bearing areas of the Saratov and Buguruslan regions. S. I. Kuznetzov. *Mikrobiologiya*, 1950, **19**, 193–201.—Microbiological formation of CH_4 may yield clues to oil deposits. Samples of water, oil, and cores from strata in which oil and gas are present were submitted to bacteriological analysis. Technique is described in some detail. Water (almost free from H_2S) from strata in the Middle Carboniferous (3000 ft) showed 10,000–25,000 bacteria per ml and cores from 1500 to 4500 ft gave bacterial counts of 100–200 million per g. Crudes vary in their suitability as growth media for desulphurizing bacteria, but some such bacteria can utilize C_6–C_7 aliphatic hydrocarbons as sources of C. Tests showed that condensation of $CO_2 + H_2O$ occurred in the laboratory over core samples. As some rocks can yield, through biological action, up to 2 g CO_2/day per ton of rock, and assuming that H_2 is present, contemporary production of CH_4 is very probable. V. B.

1629. Kuwait–Saudi-Arabia area structural test completed. Anon. *World Oil*, Mar. 1950, **130** (4), 224.—The first test in the neutral zone between Kuwait and Saudi-Arabia indicated that it was probably sited on the east flank of a structure trending north–south. Correlations were obtained with the Burgan field, 20–25 miles to the north. A further test is to be made. C. A. F.

1630. Burmah Oil abandons deep wildcat in Sind province. Anon. *World Oil*, Apr. 1950, **130** (5), 249.—The Lakhra wildcat, approx 100 miles northeast of Karachi, was abandoned after finding high-pressure water at 12,666 ft. C. A. F.

1631. Tertiary geology and principal oilfields of Burma. H. R. Tainsh. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 823–55.—Burma can be divided into four main geological and geographical districts—the Arakan coastal belt, the mountain ranges of the Arakan Yoma–Chin hills, the eastern Shan hills, and the Burma Tertiary basin. It is in the Tertiary rocks of the Irrawaddy and Chindwin River basins that all the important oilfields are located.

The author gives a brief discussion of the main Tertiary geological features, and describes the geological history of the period as indicated by stratigraphical and structural evidence.

The most important oilfields are described, and details are given of the local stratigraphic and structural developments and reservoir-rock characteristics.

E. N. T.

1632. Burmah Oil schedules test in Upper Assam jungles. Anon. *World Oil*, Mar. 1950, **130** (4), 222.—A well is to be drilled at Barsilla in a fold above the Naga thrust. Operations were abandoned at Tiru Hills after an unsuccessful test.

Attempts to reconstruct the Syriam refinery, destroyed in the war, have been prevented by civil insurrection and other factors. Operations at Yenangyaung and reconstruction of the main pipe-line have been similarly delayed. C. A. F.

1633. Structures of the northwest basin in Western Australia. E. K. Craig. *World Oil*, Mar. 1950, **130** (4), 210.—The surface geology and physiography is described for the Cape Range Dome, the Rough Range Dome, the Giralia Range, and the Minilya River section, all in the Learmouth area of the northwest basin of Western Australia.

The Cape Range Dome is formed by a large closed anticline, physiographically expressed as a northerly tapering peninsula 35 miles by 12 miles. The crest is formed of Miocene limestone. Reconnaissance indicates 1000 ft of closure.

The Rough Range Dome is elliptical and *en echelon* to the Cape Range structure. Oldest beds exposed are Middle Miocene. There is a syncline east of the structure which plunges north to form the Exmouth Gulf.

The Giralia Range is a long, gently north-plunging anticline, 15 miles east and south of the Rough Range. The east flank is faulted. Oldest beds exposed are Cretaceous bentonites and tuffs.

In the Permian Minilya River section, the shales and silt-stones are locally richly carbonaceous, and should be effective cap rocks. C. A. F.

1634. Oil possibilities in the Philippines. J. S. Teves. *World Oil*, Mar. 1950, **130** (4), 207.—Oil and gas seeps and bituminous rocks have been found in the Philippines. The islands are believed to have geological affinities with the East Indies, where the most important fields are in a series of geosynclinal basins paralleling the northeast coast of Sumatra, the north coast of Java, and the east coast of Borneo.

Oil was first reported in the islands in 1890, by Abella, from Cebu-Asturias, Toledo, and Alegria. Attempts were made to develop production in 1896, when two tests yielded small amounts of oil, but were abandoned. Several wells drilled in Cebu in 1936 had good shows. Two wells were drilled in northwestern Leyte, one of which produced a little oil. There are several seeps in the Bondoc Peninsula, and wells drilled in this area at the beginning of the century reported good shows. In Mindanao oil has been found at Pidatan and elsewhere.

A petroleum survey made between 1939 and 1941 provided detailed standard sections of the Tertiary, and extended the major tectonic provinces of the East Indies to the Philippines.

Two maps show the oil- and gas-bearing areas of the Philippines, and the tectonic provinces of southeast Asia. C. A. F.

1635. Geotectonic position of New Guinea. M. Glaessner. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 856–81.—The island of New Guinea occupies an important position in the geotectonic map of the southwestern Pacific. In this paper, the author summarizes the available data on geotectonic relations in the New Guinea area and uses this data as a basis for discussion of the fundamental structural features of this part of the Pacific margin.

The island is provisionally divided into twelve major structural sections which are briefly discussed. The difference between the northern and eastern zones and the main parts of the island are emphasized. It is pointed out that the zones of southern and central New Guinea are essentially Australian and appear to continue as a submerged median mass southeastward under the Coral Sea.

It is agreed that the various geotectonic hypotheses must be decided by further geological and geophysical work. E. N. T.

Geophysics and Geochemical Prospecting.

1636. Airborne magnetic survey checks with geologic features. Anon. *World Oil*, Mar. 1950, **130** (4), 66.—An airborne magnetometer survey in northwestern Maine has demonstrated the utility of this method of reconnaissance surveying. Because of rough terrain mean flying level was as high as 1000 ft above drainage. Traverses were made at right angles to the structural trends, and were 2 miles apart. Total magnetic intensity variations as low as 2 gammas were recorded continuously.

A composite magnetic and geological map of northwestern Maine is included. C. A. F.

1637. Offshore seismograph work with a single boat. C. J. Deegan. *Oil Gas J.*, 13.4.50, **48** (49), 82.—In using a large boat it is undesirable and uneconomic to stop while shooting, and so the seismometers must withstand continuous towing. A piezo-electric-crystal type detector in oil-filled 1¼-in plastic hose was employed. 300-ft sections were employed, each section giving one trace on the record. The crystals were about 6 ft apart, except for 25-ft blanks at each end of the hose. In making eight-trace records four 300-ft sections were coupled on each end of a blank central 300-ft section, and the shot was fired opposite the latter. The degree of buoyancy of the hose is such as to make it tend to keep at a given depth in towing. In areas of soft bottom better records have been obtained than with conventional bottom-planted seismometers. Shooting is done at 6–7 m.p.h.

Firing reels permit shots to be paid out alternately on the two sides of the boat, the shot being fired when opposite the centre of the spread.

The hose shows little wear, and sections have been in use for a year over 5000 miles of bottom with no sign of damage or wear. In heavy weather the hose can be reeled

in about 15 min. Since the elements are not directional in action no gimballs are needed.

The surveying is achieved by using sonobuoys which pick up the shots and transmit a radio signal to the boat. The times of arrival, plus the shot time and the velocity of sound in water, permit the calculation of the boat's positions. G. D. H.

Drilling.

1638. The microlog. H. G. Doll. *Oil Gas J.*, 2.3.50, **48** (43), 62.—The microlog is a resistivity log employing electrode spacings of the order of 1–2 in. The electrodes are mounted on a rubber pad and pressed against the well walls. The depth of investigation is small, and thus opposite a permeable bed the measured resistivity is determined largely by the filter-cake, and any included adjacent rock will be filtrate charged. The short spacing will be more influenced by mud cake than the wide spacing, and so usually gives a lower apparent resistivity, and this is considered to indicate the presence of permeable beds. Opposite an impermeable bed both spacings give the same resistivity for low-resistivity beds, but for high-resistivity beds the measurements may differ appreciably. For intermediate resistivities the long spacing will give the lower apparent resistivity.

The device is of value in accurately delineating permeable beds when the S.P. log alone is unsatisfactory, and has been applied in limestone areas, and in sand and shale formations. G. D. H.

1639. Some preliminary investigations of quantitative interpretations of radio-activity. R. E. Bush and E. S. Mardock. *Petrol. Tech.*, Jan. 1950, **2** (1), *A.I.M.M.E. Tech. Paper No.* 2780, 19–34.—The theoretical basis of radioactivity logging is discussed briefly, and the means of obtaining the logs are described. The neutron log in a hole of uniform bore is determined mainly by two factors: a chemical factor dependent on the rock composition, and the absorption coefficient of the rock for the neutron flux. The latter is dependent principally on the hydrogen content of the rock, and is therefore influenced chiefly by the fluids in the pores. The rock volume affecting radioactive logs is much greater than is involved in coring, cuttings, and sidewall samples. Hence radioactive logs should be better than rock samples in rocks of variable porosity.

By compiling curves relating porosity and neutron log readings for a base well, and provided that casing and lithological conditions are not too divergent, the relationships can be utilized for interpreting later neutron curves in terms of porosity. The method is described. Homogeneous limestones such as oolites show less dispersion of the observations than do heterogeneous limestones such as the Edwards limestone and dolomite, and the Permian dolomites. The method is relative, and application to rocks other than limestones is not attempted because of the variability of such rocks. G. D. H.

Production.

1640. Phase equilibria in hydrocarbon–water systems. O. L. Culberson, A. B. Horn, and J. J. McKetta. *Petrol. Tech.*, Jan. 1950, **1** (2), *A.I.M.M.E. Tech. Paper No.* 2778, 1–6.—A study of the phase equilibria of hydrocarbon–water systems has been initiated at the University of Texas. The apparatus utilizes a 550-c.c. equilibrium cell in an air-bath. Temps are controlled to $\pm 1°$ F, and pressures up to 10,000 p.s.i.a. can be measured. The details of the apparatus are described, and the analytical and operating procedures outlined. The equipment was checked by comparing data obtained for the solubility of methane in water at 77° F and 10,000 p.s.i.a. with published data.

The solubility of ethane in water at temps of 100°, 160°, 220°, and 340° F at pressures up to 1200 p.s.i.a. has been studied, and the results are given in tabular and graphical form. Henry's law is obeyed closely up to 300 p.s.i.a. at 100° F, 600 p.s.i.a. at 160° and 280° F, and 400 p.s.i.a. at 280° and 340° F. Cross-plots of the data indicate solubility minima at about 180–210° F for pressures from 300 to 1200 p.s.i.a., and a max at about 290° F at 300 p.s.i.a.

Published data for hydrogen–water, and methane–*n*-butane water and the present pressure solubility data appear to converge at about 200 p.s.i.a. G. D. H.

Oilfield Development.

1641. World production. D. M. Duff. *Oil Gas J.*, 23.3.50, **48** (46), 166.—U.S.A. oil production in January 1950 averaged 4,934,000 b.d., a fall of 90,000 b.d. compared with December 1949. Venezuela produced 1,464,900 b.d. in January 1950, Kuwait 275,000 b.d., Canada 57,500 b.d., Colombia 81,300 b.d., Egypt 45,500 b.d., and Indonesia 122,500 b.d. Russia is estimated to have produced 730,000 b.d., and the world daily output is placed at 9,534,800 brl, compared with 9,589,300 brl in December 1949.

Tables give the daily outputs by countries for January and December 1949, and January 1950, with the monthly outputs for the Middle East and western hemisphere (omitting U.S.A.) from February onwards. G. D. H.

1642. Record shows poor payout below 12,000 ft. R. D. Shrewsbury. *World Oil*, Mar. 1950, **130** (4), 48.—An analysis of results of deep tests has shown that, drilling below 12,000 ft, in the U.S.A., will not add materially to the country's reserves. More than 600 wells have been drilled below 12,000 ft, of which approx thirty were classed as successful.

In normal oilfield development, percentage recovery has been small, due to low temps and pressures, and high viscs. Artificial water drives and natural-gas repressuring are relatively inefficient. It is suggested that re-pressuring with hydrogen would be an effective means of recovering " lost " oil. C. A. F.

1643. Completions top 1949 period. Anon. *World Oil*, Mar. 1950, **130** (4), 34.—3376 wells were completed in the U.S. in January, 12·4% more than in the same month in 1949. Average depth of wells was 3869 ft, compared with 3666 ft in January 1949.

A table gives well completions in the U.S. during January 1950, by states.

C. A. F.

1644. Exploration highly successful in January. Anon. *World Oil*, Mar. 1950, **130** (4), 77.—633 wells were completed in the U.S.A. in January 1950, 23% more than in the same month of 1949. 79·8% were dry, 20·2% found pay, and there were eighty-one new crude sources, including fifty-nine new fields and twenty-two new pays in established fields. Sixteen gas pools were discovered, of which fourteen were new fields.

A table gives mechanical, geological, and production data for new oil, distillate, and gas fields and new pays discovered in the U.S.A. in January 1950, by states.

C. A. F.

1645. Drilling in Ohio drops in 1949. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-80.—1052 wells were drilled in Ohio in 1949, of which 626 were successful. In 1948, 1231 wells were drilled, of which 376 found gas, 277 oil, and 114 oil and gas.

1949 new reserves added, based on initial deliveries, were 215,883,000 cu. ft. gas and 8568 b.d. oil. Largest gas well drilled was 1 C. G. Longshore, which had an initial production of 10,416,000 cu. ft. under 850 p.s.i. Largest oil producer was 1 H. C. Albert in Perry County, which initially produced 275 b.d. C. A. F.

1646. Deep discoveries increase Mexico's oil reserves. J. L. Cumming. *World Oil*, Mar. 1950, **130** (4), 225.—Estimated Mexican reserves in 1939 were 600 million brl. As a result of deep discoveries and extensions to existing fields in recent years, reserves are now estimated to be 1–10 billion brl. C. A. F.

1647. Fewer rigs. Anon. *Oil Gas J.*, 2.3.50, **48** (43), 36.—Ninety-six rigs (fifty-seven field, twenty-two exploratory, seventeen workover) were operating in Venezuela in January, five fewer than in December 1949.

A 6825-ft well in Pedernales has produced 1272 b.d. initially. G. D. H.

1648. Oil Search in France. L. Dumas. *Bull. Ass. franç. Tech. Pétrole*, Feb. 1950 (79), 29–42.—St Marcet, discovered in 1939, produces much gas and a little oil. The gas was found at 1600 m and had a pressure of about 150 kg/sq. cm.; the reserves are placed at 5,000,000,000 cu. m., which is equivalent to 1,500,000 cu. m. of gasoline.

In July 1949 a well at Soulz-sous-Forêts gave 1000 tonnes of oil in two days, and on regular production it has given 60 cu. m/day. The oil is of good quality, and the geological data give hopes for structural continuity hitherto unknown in this Alsace basin.

In southern France a structure at Bastennes has shown oil impregnation, and a small production has been obtained at Garlin near Pau. Good impregnation with heavy oil has been found in the Alès-Maruéjols basin, and a small production on a buried structure at Coulobres near Béziers. High-pressure gas has been met at Vaunage, near Nîmes.

In North Africa the principal development was the discovery in 1947 of Oued Beth, which has given 30,000–40,000 tonnes/year. There are twelve wells, and recently two new productive areas have been found 2 and 10 km from Oued Beth. In the Chelif Valley of Algeria good indications of light oil and gas have been found, thus confirming the presence of oil in this basin, which was indicated by Tliouanet. Five wells at Sidi-Aissa near Aumale, have given an output of 12 cu. m/day. At Cap Bon in Tunisia a gas flow at 180 kg/sq. cm. with considerable distillate has been obtained.

French territorial production in 1949 was 220,000,000 cu. m. of gas, 15,000 tonnes of liquid products (butane, etc.), and 85,000 cu. m. of crude; the 1939 figure was 70,000 tonnes of oil. The cost of the investigations in 1949 was 10,000,000,000 francs, and the total for 1946–50 will be 30,000–50,000 million fr. The St Marcet discovery is valued at 40,000,000,000 fr.

Comparison of search effort in the U.S.A. and French territory in 1949, on the basis of oil consumption, indicates that France should have about sixty wildcat rigs (there were thirty-two); French exploratory drilling should have had 400 wells aggregating 500 km (there were 110 wells totalling 145 km). Assuming a U.S.A. cost of 50 c/brl for exploration, France should have spent 18,000,000,000 fr. In the light of the above figures French effort should be doubled to be comparable with consumption. In view of transport costs France could work poor deposits. France should aim at locating reserves of 180,000,000 tonnes, which, in terms of U.S. figures, might cost 250,000,000,000 fr, or 400,000,000,000 fr if allowance is made for importing equipment, etc. (40,000,000,000 fr/year for ten years). Under present economic conditions expenditure of this magnitude is not possible, but a sustained figure of 18,000,000,000 fr/year should permit 5,000,000 tonnes/year to be reached in ten years. The benefits would appear progressively. 800,000,000,000 fr/year is spent on social security and 400,000,000,000 fr/year on armed forces. The suggested expenditure on oil search would increase the military strength and would be only a quarter of the tax income from gasoline and oil.

Two organizations have been created to deal with technical aspects of the search for oil. G. D. H.

1649. Summary of petroleum exploration activities in France and the French Union. Anon. *Rev. Inst. franç. Pétrole*, 1950, **5**, 195–8.—Development wells (12,141 m) and wildcats (27,148 m) drilled in the second half of 1949 are tabulated, according to operating company, together with a forecast for the first half of 1950. Total French daily production rate at Jan. 1, 1950, was 261 m^3 crude and 790,000 m^3 gas.

V. B.

1650. Germany's gas production off 19 percent from 1948. Anon. *World Oil*, Apr. 1950, **130** (5), 244.—1921 M.c.f. gas were produced in Germany in 1949, 19% less than in 1948, due to limited market outlets. Bentheim produced 1663 M.c.f. Reitbrook, 85 M.c.f., and Steimbke-Rodewald 60 M.c.f. C. A. F.

1651. The importance of the Middle East in the world oil supplies. M. Mercier. *Bull. Ass. franç. Tech. Pétrol.*, Feb. 1950, (79), 43–50.—Middle East reserves were estimated at 22,175,000,000 brl in 1940, and 32,600,000,000 brl in 1949. Out of a world total of 78,000,000,000 brl, the U.S.A. has 28,000,000,000 brl and Venezuela 9,000,000,000 brl. The Middle East has 42% of world reserves, but gives only 10% of the production; the U.S.A. with 33·9% of the reserves, gives 64% of the output; the Caribbean with 10% of the reserves, gives 17% of the world output.

Other comparisons reveal that in 1953 the Iraq Petroleum Co. will have a potential

output of the order of 32,000,000 tonnes/year, assuming that the necessary pipe-lines are available. Adding on the output of Aramco and the Dutch and British interests a figure of the order of 129,700,000 tonnes/year is predicted for the Middle East in 1953.

The developments at Dhahran are of very considerable importance, and in building Tapline certain problems have been solved. The pipe was of 30-in and 31-in diameter so that telescoped transportation was possible, and this method is expected to be used by the I.P.C., though with a slightly different larger size. The proposed I.P.C. line will be half the length of Tapline, and pipe transportation will be much easier. Pipe-laying is planned to start at the beginning of 1951, and the capacity is placed at 13,000,000 tonnes/year for three stations; four supplementary stations would raise the figure to 25,000,000 tons. The cost is estimated by Metz at £40,000,000. The annual value of oil transported by the line may be about $225,000,000 and a 23·7% share considered as French will be welcome in 1952 when Marshall aid ends.

G. D. H.

1652. Production in Saudi-Arabia. Anon. *Petrol. Engr*, Mar. 1950, **22** (3), B-76.—13,947,930 brl, or 449,933 b.d., were produced in Saudi-Arabia in January 1950, compared with 462,363 b.d. during the preceding month. C. A. F.

1653. Production in Saudi-Arabia dips 12 per cent in 3 months. Anon. *Petrol. Engr*, May 1950, **22** (5), B-76.—12,757,608 brl, or 411,536 b.d., were produced in Saudi-Arabia during March 1950. For the first three months of 1950 production was 40,605,823 brl, compared with 46,328,665 brl during the same period in 1949.

C. A. F.

Transport and Storage.

1654. Flowmeter research and the ASME. S. R. Beitler. *Mech. Engng*, May 1950, **72** (5), 376.—The paper tells of the research and development work on fluid-flow measurement which has been done to date by the A.S.M.E. The period of time covered by the article commences at 1884 and from that time to 1916 thirty-seven papers on flow measurement were presented at meetings of the A.S.M.E. The titles of the more important of these reports are given, and the progress made by the Fluid Meters Committee formed in 1916 is indicated. In addition to the publication programme carried out by the Committee, research was initiated in collaboration with the American Gas Association. Subsequent research work on the use of orifices and nozzles for measuring oil flow was started in 1932 at the University of Oklahoma. Later research work is described, and an indication is given of the many fluid-metering problems which require further investigation. A. S.

1655. Creole-Shell Siburua water line is coated inside by new method. R. L. Buck. *Oil Gas J.*, 25.5.50, **49** (3), 114.—Practices developed for the first successful operations for internal coating of pipe as long as three-joint sections are described.

Line varies in dia from 20 to 34 in and will supply fresh water from Con Fulcon, Venezuela, to refineries and villages 130 km distant.

Line operates by gravity. Before coating internally with hot pipe-line enamel, line is thoroughly cleaned inside, then primed by a large-capacity paint spray gun. Pipe is now rotated and hot inside enamel pumped into paint head and flow of paint automatically controlled.

Pipe joints finally enamelled on field-site. G. A. C.

Refinery Operations.

Refineries and Auxiliary Refinery Plant.

1656. Steam power station auxiliaries. T. H. Carr. *Mech. World*, 2.6.50, **127** (3307), 617.—Power-station auxiliary load is often quite appreciable, and may represent anything from 3 to 9% of the total station load. The amount of auxiliary plant

varies in each station, due in particular to the site conditions obtaining and the type of plants installed. Site conditions will affect the circulating water, and coal- and ash-handling plants, while the steam pressure adopted will materially affect the boiler-feed-pump auxiliary power. Careful planning of auxiliary system can result in considerable savings. Auxiliary power plant can be grouped broadly as follows: (*a*) steam-driven auxiliaries, (*b*) electrically-driven auxiliaries. Trend in recent years has been from steam to electric drive, due to simplicity and flexibility of latter, together with the important changes in boiler and turbine practice. The paper concludes with a general discussion of essential and non-essential auxiliaries. A. S.

1657. Mechanism of boiling. R. J. J. Hamblin. *Birm. Univ. Chem. Engr*, Mar. 1950, **1** (2), 42.—A theoretical investigation, using thirty literature references, into the mechanism of boiling. The effects of various types of boiling on the H.T.C. are discussed. The bulk superheat of a boiling liq depends less on heating rate than upon the type of boiling. It is considered that bubble nucleation is a surface effect in which micro-irregularities play a large part. The initial surface properties at the liquid–solid heater interface is therefore of great importance, and small amounts of contaminants which vary the interfacial energy will affect greatly the type of boiling, and the heating rate for a given temp difference. Control can be exercised on foaming, on degree of superheat, on heat-transfer rate for a given temp difference, and on the film boiling temp by the choice of surface and the use of additives. D. F. J.

1658. The boiler plant of Petrochemicals Limited. Anon. *Mech. World*, 26.5.50, **127** (3306), 587.—The above plant is unusual in that the large water-tube boilers are in the open air and that de-oiled condensate is used as feed water for high-pressure boilers. The erection of the boilers in the open results in a considerable saving on building costs. The paper describes the boilers and boiler-house and gives details of steam pressure and temp control, the power plant and electrical distribution. Only pure mineral oil is used for lubricating purposes throughout the plant, the use of compounded oil being strictly prohibited. De-oiling of the condensate is carried out by gravity separation and also by electrical means. The electrolytic de-oiling plant works very well, but attention is necessary to a number of points, including maintenance of correct conductivity and use of correct electrolyte. A. S.

1659. Designing refrigerant piping. T. G. Hicks. *Mech. World*, 2.6.50, **127** (3307), 613.—Although suction and discharge piping represents less than 10% of total equipment cost for refrigerating plant, yet undersize suction and discharge piping can result in an increase in annual operating costs of 5–30%, depending on the pressure drops in the pipe. Pipe-size selection is therefore an economic problem, an analysis of which is made in this paper. The effect of pressure loss on operating conditions is discussed, and a graph shows the effect of increased head or discharge pressure on ammonia compressor input power and capacity. This illustrates that power input increases rapidly, and capacity decreases as head or discharge pressure increases above normal. When undersize piping has been fitted the remedy in the past has been to instal a smaller machine to carry that portion of the load which the large machine cannot handle. This is obviously wasteful, and a graph is given showing the savings resulting from reduction of the discharge pressure of electrically driven ammonia compressors. Compressor manufacturers and plant operators rely on plant design to properly size all piping in the system. Designers must therefore avoid the false economy resulting from the use of undersize piping in refrigerating systems. A. S.

1660. Modern laboratory and pilot plant apparatus for petroleum refining industry. S. Niementowski. *Nafta*, Jan.–Feb. 1949, **5**, 19–24; Mar. 1949, **5**, 57–61.—Modern petroleum refining processes demand appropriate laboratory and pilot plant apparatus for process control and experimental work. Such apparatus is urgently needed in Poland.

Sketches are given and described of laboratory apparatus for single evaporation and T.B.P. and their use for crude analysis is suggested.

Author mentions his deasphalting apparatus, 220 mm dia, which he made in 1933–34 and gives a diagram of counter-current apparatus describing its working and capa-

bilities. Laboratory and pilot-plant equipment for filtration are described, as is a solvent-refining column 2·5 m high set up in Jedlicz. M. S.

1661. Heat transmission in shell-boiler smoke tubes. Parts 1 to 4. N. Y. Kirov. *J. Inst. Fuel*, 1950, **23**, 121.—The relative importance of various factors affecting the transmission of heat in shell-boiler smoke tubes is analysed.

The paper is divided into four parts: the influence of scale, fouling of heating surfaces in contact with flue gases, heat transfer to boiling water, and heat transfer by convection in boiler smoke tubes.

It is shown that the overall heat-transfer rates in shell-boiler smoke tubes are controlled by the individual convection coefficient between the flowing gas and the heating surface. A simplified method for its calculation, giving good correlation with experimental data, is described. Numerous diagrams and tables of data are presented. There are thirty-three literature references. The article is to be concluded. D. K.

1662. Liquid fuel burning. W. Carroll. *J. Inst. Cert. Engrs, S. Africa*, Feb. 1950, **23** (2), 26–45.—The properties of four grades of petroleum fuels and coal-tar fuels, 100, 200, and 400, and the required storage facilities and atomizing temperatures are given. Delivery and storage and delivery of fuels to burners by pump and gravity systems are briefly outlined. Steam and electrical heating of fuel-lines and the lagging of lines emphasized particularly for coal-tar fuels. Diagrams of the foregoing are shown. The following are discussed with respect to burning: excess of air, draught control, and life of brickwork. It is noted that fine atomization is of primary importance with respect to brickwork life, and to overcome detrimental effect of ferric oxide content of tar fuels on silica firebricks, the latter should contain a high alumina content. Types of burners are described and illustrated by drawings and diagrams showing construction of low-, medium-, and high-pressure air-burners (fixed and controlled types), and steam-jet burners for both kinds of fuel. Their advantages, disadvantages, and application are discussed. Automatic controls for the following are described and illustrated, and their use described: high-low flame type, LE; high-low flame differential-pressure type, LDE. Variable flame control, VAS, VDR, VDAS, and VDS. Boiler installations are described briefly and are shown in six plans and illustrations. Nine pages of discussion by four contributors, which much augment the information on the subject, and the author's replies thereto are given. W. H. C.

1663. Pressure-maintenance and hydrocarbon-recovery plant at Seeligson. D. T. McDonald. *Oil Gas J.*, 11.5.50, **49** (1), 78.—A plant has been installed at Jim Wells County, Texas, to handle 150,000,000 cu. ft. daily cycle gas and 70,000,000 cu. ft. daily oil-well gas at an assured propane-extraction efficiency of 75%.

The plant is capable of producing propane, *iso*butane, normal butane, gasoline, naphtha, kerosine, absorption oil, and residuum as stock tank products. Steps include cycle-gas absorption, casinghead gas absorption, re-absorption, propanizer re-absorber, distillation raw-product splitter, light and heavy ends fractionation. The plant is operated by the Magnolia Petroleum Co. G. A. C.

1664. Separation of oil refinery waste water. R. F. Weston. *Industr. Engng Chem.*, 1950, **42** (4), 607–12. (*Industrial Waste Treatment Symposium—Divn of Water, Sewage, and Sanitation Chemistry 116th meeting Amer. Chem. Soc. Sept.* 1949.)—Disposal of oil-refinery waste waters includes separation, collection, and re-conditioning of oil for recharging to refinery processes and treatment of waste water to render it fit for disposal. Differential gravity separators first separate the oil from water. Their operation depends on the amount of oil amenable to separation by gravity flotation. Experiments are described to determine non-separable oil content of a sample. The separated oil contains suspended solids and water which may interfere with processing. Slop oils are therefore treated prior to recharging. An automatic backwash sand filter and pilot plant biological filters for separator effluents are described which substantially reduce oil content. R. G. T.

Distillation.

1665. Continuous fractionating columns for pilot plant. J. K. Carpenter and R. W. Helwig. *Industr. Engng Chem.*, 1950, **42** (3), 571–8.—Description of design and construction features of pilot-plant continuous fractionating columns charging a wide variety of hydrocarbon fractions includes columns of packed-tower type from 2·5 to 12-in-dia up to 25 ft in height and operating pressure 10 mm to 300 p.s.i.g. High-pressure, atmospheric, and vacuum distillation systems are described with illustrations of construction of preheaters, reboilers, condensers, packing supports, thermowells, windings, and instrumentation. R. G. T.

1666. Volumetric and phase behaviour of propene-1-butene system. G. M. Goff, P. S. Farrington, and B. H. Sage. *Industr. Engng Chem*, 1950, **42** (4), 735–43.—Results of experimental investigations of volumetric behaviour of four mixtures of propene and 1-butene are described. Seven temps between 40° and 280° F and pressures up to 10,000 p.s.i. were used. Compositions and specific volumes of coexisting phases were established throughout the two-phase region above 40° F. Equilibrium constants for propane and 1-butene are reported as functions of state. Graphical and tabular results are presented. R. G. T.

1667. Isopieotic liquid–vapour equilibria calculated from other equilibria of binary systems. S. E. Wood. *Industr. Engng Chem.*, 1950, **42** (4), 660–4.—Scatchard's thermodynamic method for calc of one set of equilibria data from another set is applied to the calc of b.p. diagrams. Thus b.p. diagram for benzene–methanol at 1 atm has been calc from v.p. data. Calc to obtain b.p. diagrams at any press and to allow for variation of activity coeffs with temp are described. Procedure for similar calc for ternary systems is discussed. R. G. T.

1668. Hydrodynamics of liquid–vapour flow in packed distillation columns. T. M. Reed, III, and M. R. Fenske. *Industr. Engng Chem.*, 1950, **42** (4), 654–60.—Data obtained in columns packed with single-turn helices are used to confirm a correlation between packing dimensions, phase properties, and operating conditions with counter-current two-phase flow. Other types of laboratory distillation column packings follow approx the same correlation. Applications of simplified forms are mentioned. Effect of vapour density on pressure drop, operating pressure on throughput, and phase densities on the flood point are discussed. Value of n in $\Delta p = kG^n$ is examined and values greater than the turbulent max of 2 are shown to be consistent with conditions under which a distillation column operates. R. G. T.

1669. *n*-Decane–*trans*-decahydronaphthalene. Binary mixture for determining efficiencies of fractionating columns operating at reduced pressures. M. R. Fenske, H. S. Myers, and Dorothy Quiggle. *Industr. Engng Chem.*, 1950, **42** (4), 649–53.—A distillation unit having the equivalent of two theoretical plates has been usde to obtain vapour–liq equilibrium data for binary system—*n*-decane–*trans*-Decalin between 50 mm Hg absolute and atm pressure. The relative volatility is constant over the composition range at a given pressure. Relative volatility increases with pressure and enables the investigation at total reflux of fractionating sections having 34 and 22 theoretical plates at the two pressures mentioned. Possibility of using binary mixtures of *trans*-Decalin and *cis*-Decalin and of *cyclo*hexyl*cyclo*hexane and *cyclo*-hexylbenzene for determining fractionating column of efficiency is discussed. R. G. T.

Cracking.

1670. Pressure drop of fluids in single phase flow through a layer of catalyst. H. Verschoor. *Ingenieur*, 2.6.50, **62** (22), Ch. 29.—The author emphasizes the importance of evolving a method for the prior determination of pressure drops in fixed-bed catalyst reactors, since it is the gas flow through such reactors that determines the heat-transfer

rate on which the economics of the process so largely depend. Two concepts are proposed :

(*a*) The course of the fluid is only through those channels running parallel to the direction of flow, and the pressure drop consists largely of contraction and expansion losses in the flow channels.

(*b*) The fluid tends to follow a path of constant cross-section irrespective of the direction.

Carman, who has made a review of possible theories in this field, concludes that experimental evidence supports the latter concept. Furthermore, the method is particularly attractive in that it is necessary to know only the external area of the catalyst per unit volume of packed space and the intergranular porosity of the layer *in situ*. These two factors can be determined in a simple laboratory apparatus. Experimental data covering both streamline and turbulent flow conditions are given to illustrate the applicability of the correlation. R. R.

1671. Platinum reforming of gasoline. M. L. Kastens and R. Sutherland. *Industr. Engng Chem.*, 1950, **42** (4), 582–93.—This staff–industry collaborative report first reviews marketing requirements of gasoline and various refining processes—cracking, alkylation, polymerization, and desulphurization. Reforming was found necessary to produce more desirable products from straight-run gasoline. A new catalytic reforming process is described using a platinum catalyst for conversion of naphthenes to aromatics, the hydro-cracking of paraffins, isomerization of paraffins, and complete desulphurization in a single non-regenerative cat process. Each type of conversion is discussed, and the effect of temp, space velocity, pressure, and hydrogen recycle rate are briefly described. A platforming unit is fully described with flow sheet, and review of capital and operating costs. The platformate boils slightly higher than the charge. Author concludes platforming will produce a gasoline up to 100 O.N. with small yield loss but plants will probably be operated to give a product of O.N. 93 with Road Octane rating approaching 100. R. G. T.

Hydrogenation.

1672. Progress review No. 7. The hydrogenation and Fischer–Tropsch processes. C. C. Hall. *J. Inst. Fuel*, 1950, **23**, 148.—The commercial development of both the hydrogenation and Fischer–Tropsch processes, particularly in Germany, Britain, and the U.S.A., is discussed. The pre-war hydrogenation processes in Britain and Germany are described. The main advance in the German process during the war was an increase in operating pressure from 200–300 atm to 700 atm. A new catalyst for the vapour phase, K535 (Mo–Cr–Zn), was developed. I.C.I. developed an iron catalyst to replace tungsten in the final vapour-phase stage. By using this catalyst and blending the product with *iso*-octane, 100-octane fuel was produced. Butanes were processed to give *iso*-octane and alkylate for upgrading of fuels. Hirst *et al* of the U.S. Bureau of Mines published a paper outlining a proposed design of plant which should have an overall efficiency of 55%. Principal modifications contributing to this result are briefly discussed. Recent work at U.S. Bureau of Mines suggests initial reaction in coal hydrogenation is rupture of carbon-to-oxygen bonds, fragments formed stabilized by addition of hydrogen to form asphaltic compounds. Further conversion of these to liquids and light hydrocarbons is thought to involve carbon-to-carbon linkages.

The production of synthesis gas for the Fischer–Tropsch process and the process itself are discussed. The process used in Germany employed a kieselguhr-supported cobalt catalyst, but this is expensive, and a cheaper iron catalyst now replaces it.

The fluid-bed process was found to have its limitations. It is suitable only for the production of petrol or other low-boiling products.

Reaction mechanisms and economics are discussed. There are twelve literature references. D. K.

1673. Hydrogenation of coal in a fluidized bed. E. L. Claric, M. G. Pelipetz, H. H. Storch, S. Weller, and S. Schreiber. *Industr. Engng Chem.*, 1950, **42** (5), 861–5. (*116th Meeting Amer. Chem. Soc., Divn of Gas and Fuel Chem.*)—Laboratory-scale hydrogena-

tion of coal in a fluidized bed at 250–1000 p.s.i.g. and temps of 500–600° C has produced oil and hydrocarbon gas yields of 20–27% of moisture- and ash-free coal—yields which permit possible consideration as synthetic fuel producer. Comparison of fluidized hydrogenation with modernized Bergius–I.G. process suggests lower-pressure fluidized process may be more economical. Disadvantages of Bergius process: slurry handling and deleterious effect of recycle oil are also eliminated in the dry process. Pilot-scale plant is under construction. R. G. T.

1674. Phenols in oil obtained from hydrogenation of coal—separation and identification. E. O. Woolfolk, M. Orchin, and M. F. Dull. *Industr. Engng Chem.*, 1950, **42** (3), 552–6.—Hydrogenation of a Bruceton coal yielded a tar-acid fraction of the *n*-hexane soluble portion of the liquid product containing 9·4% tar acids by wt of the *n*-hexane-soluble oil. The acid fraction was distilled to 136 fractions which were combined into 70 b.p. and refractive index fractions. Sixteen individual phenols were isolated and identified from several of the fractions, and fourteen were quantitatively estimated by infra-red spectrophotometry. R. G. T.

Special Processes.

1675. Ammonia manufacture from St Marcet natural gas. J. Vergues and M. Patry. *Chim. et Ind.*, 1950, **63**, 487–93.—St Marcet gas (CH_4 92, C_2 and higher 5, N_2 3%) is used in two plants for H_2 manufacture for eventual production of NH_3. At Toulouse reaction with steam over Ni cat proceeds according to $CH_4 + H_2O = CO + 3H_2$. Reaction occurs in alloy-steel (Cr–Ni) tubes, externally heated by gas. On leaving this primary furnace CH_4 content of gas (2%) is reduced to 0·3% max in a post-combustion furnace (Ni cat), into which air is injected, operating at 900° C. Gas is then cooled to 400–500° C and passed to CO conversion (Fe cat) furnace ($CO + H_2O = CO_2 + H_2$). Plant capacity is 600,000 m³/day of gas (CO_2 16, CO 3, H_2 60·6, CH_4 0·3, N_2 20·1%) and uses 194,000 m³/day gas as fuel. Purification of gas is by water (25 atm) washing and NaOH to remove CO_2 (which is used industrially) and cuprous solution for CO removal. Other plant (Pierrefitte) employs partial combustion in O_2-enriched air ($CH_4 + \frac{1}{2}O_2 = CO + 2H_2$) using a conversion cat. Special precautions, including steam injection, are necessary to prevent carbon-black formation. Plant can handle 25,000 m³/day of CH_4. Gas purification is as at Toulouse. Flow diagrams of both plants are given. V. B.

Metering and Control.

1676. Automatic lubricators in flow-meter service. R. F. Carlson. *Oil Gas J.*, 11.5.50, **49** (1), 100.—A new type " excess-pressure " lubricator for recording-orifice meters is described.

The lubricant is maintained under a pressure slightly in excess of that on the product being metered, irrespective of whether the line pressure is a few hundreds or several thousand lb. A light grease is employed. Experience has shown that the lubricators require filling on an average, once annually. G. A. C.

Products.

Chemistry and Physics.

1677. Chemical characterization of catalysts. I. Poisoning of cracking catalysts by nitrogen compounds and potassium ion. G. A. Mills, E. R. Boedeker, and A. G. Oblad. *J. Amer. chem. Soc.*, 1950, **72**, 1554–60.—The effect of basic nitrogen compounds, such as quinoline, and of potassium ion on silica–alumina(–magnesia–zirconia) cracking catalysts has been investigated. Cumene and light East Texas Gas Oil were used as charging stock. Catalysts poisoned with quinoline or potassium ion gave lower yields of benzene, coke, and gas in the dealkylation of cumene, and lower yields of gasoline, coke, and gas in the cracking of light East Texas gas oil than freshly calcined catalyst. It was shown that some of the adsorbed quinoline could be readily removed from the catalyst by flushing with nitrogen; this is referred to as physically adsorbed quinoline,

and the more tenaciously held quinoline as chemisorbed. By studying partially poisoned catalysts, an exponential relationship was found between chemisorbed organic nitrogen compounds and the activity of the catalyst in the dealkylation of cumene. It was also shown that the amount of quinoline chemisorbed was related to the cracking activity of the catalysts as measured by the gasoline yield from light East Texas gas oil. From the chemical nature of the catalyst poisons and the quantity chemisorbed it was concluded that the catalytically active area of the catalyst was " acidic," and comprised a relatively small fraction of the total catalyst area.

W. H. A.

1678. Alkyl tetrahydronaphthalenes. II. R. T. Hart, W. J. Georgitis, and R. H. Wells. *J. Amer. chem. Soc.*, 1950, **72**, 1249–51.—Twenty new 6-alkyl and 6 : 7-dialky-tetra-hydronaphthalenes have been prepared and their physical constants determined. When segregated into groups according to molecular types it was shown that a linear relationship existed between the boiling points and the number of carbon atoms. An empirical relationship between refractive index and density is reported for these hydrocarbons. W. H. A.

1679. Some reactions of *t*-butylethylene. G. G. Ecke, N. C. Cook, and F. C. Whitmore. *J. Amer. chem. Soc.*, 1950, **72**, 1511–13.—The reaction of *t*-butylethylene with chlorine, hydrogen chloride, and hydrogen iodide has been investigated. The reaction with chlorine yielded 53% of 1 : 2-dichloro-3 : 3-dimethylbutane, together with unreacted olefin, unsaturated dichlorides, and a mixture of higher chlorides ; dehydrochlorination of the saturated dichloride yielded a mixture 2-chloro-3 : 3-dimethyl-1-butene and 1-chloro-3 : 3-dimethyl-1-butene. Addition of hydrogen chloride to *t*-butylethylene in the absence of catalysts gave a mixture of 2-chloro-2 : 3-dimethyl butane (re-arranged chloride) and 2-chloro-3 : 3-dimethylbutane (Pinacolyl Chloride) in which the re-arranged chloride predominated. The presence of peroxide in the reaction mixture at low hydrogen chloride ratios resulted in the normal addition product predominating over the re-arranged one ; in addition, the abnormal addition product 1-chloro-3 : 3-dimethylbutane was also formed. At high hydrogen chloride ratios the peroxide has no effect on the reaction. In the reaction with hydrogen iodide 90% of unre-arranged and 10% of re-arranged iodide were formed. Possible mechanisms of these reactions are discussed. W. H. A.

1680. The low temperature, low pressure, hydrogen atom initiated combustion of hydrocarbons. E. J. Badin. *J. Amer. chem. Soc.*, 1950, **72**, 1550–3.—Atomic hydrogen initiated reactions between hydrocarbons and oxygen at 20° C and 0·20–0·55 mm pressure have been studied. *iso*Butane was studied in greater detail than the hydrocarbons methane, propane, propylene, *n*-butane, 1-butene, and 2-butene. The primary oxidation products of *iso*butane are formaldehyde and acetone in approx equal volumes. The suggested mechanism of paraffin oxidation involves initial dehydrogenation, followed by the formation of an unstable peroxide compound which is probably of a hydroperoxide nature. Further reaction may follow one of two courses : in the first the peroxide is stabilized by a third body when no aldehyde or ketone is formed, and in the second further reaction or dissociation of the unstable peroxide results in the formation of aldehyde and ketone. The conditions which influence the course followed by the unstable peroxide compound are discussed.

W. H. A.

1681. Two-stage combustion process of higher hydrocarbons and their derivatives. K. Spence and D. T. A. Townend. *Rev. Inst. franç. Pétrole*, 1949, **4**, 389–404.—Review is made of present state of knowledge of the two stages in the combustion of higher hydrocarbons : (1) the initiation and propagation of cool flames subsequent to the initial slow-combustion processes and (2) the initiation of the second-stage flame in the " cool "-flame products. E. B.

1682. Mechanism of cyanogen combustion. Effect of extraneous gases on the flame luminosity and interpretation of their action. G. Pannetier. *Rev. Inst. franç. Pétrole*, 1949, **4**, 418–23.—Experimental observations of the cyanogen flame and its spectral changes and radiation decrease, when H_2, Cl_2, or NO were introduced, have provided

evidence for the discussion of the combustion mechanism of CN in O_2 and of some reactions involving free radicals, including C_2, CH, CCl, CN, OH. E. B.

1683. Mechanism of combustion in gases. H. B. Milner. *Nature*, 1950, **165**, 597.—Summary of papers on the kinetics and mechanism of burning and combustion reactions held in Paris, April–May 1948, under the auspices of the National Centre of Scientific Research. The complete papers and discussions appeared in the *Revue de l'Institut Français du Pétrole et Annales des Combustibles Liquides* in 1949. H. C. E.

1684. Photochemical formation of sulphinic acids from sulphur dioxide and hydrocarbons. F. S. Dainton and K. J. Ivin. *Trans. Faraday Soc.*, 1950, **46**, 374–81.—$RH + SO_2 \longrightarrow R{\cdot}SO{\cdot}OH$ (where RH is a paraffin or olefin) occurs in the gas phase in presence of U.V. light with a quantum yield of < 1 in all cases. Reaction, which affords a new method of preparation of aliphatic sulphinic acids, proceeds most readily with long-chain paraffins, and the order of ease of attack appears to be tert > sec > primary. Olefins are less reactive than paraffins, due to their high quenching ability with respect to excited SO_2. E. B.

1685. Polymerization of *iso*butene by boron trifluoride. A. G. Evans and G. W. Meadows. *Trans. Faraday Soc.*, 1950, **46**, 327–31.—Experiments are described which establish that the low-temp (− 80° C) high mol.-wt. polymerization of *iso*butene by BF_3 requires a co-cat (*e.g.*, such as may be present in impure materials or vessel walls). Results are discussed. E. B.

1686. Calculation of complex equilibrium relations. H. J. Kandiner and S. R. Brinkley, Jr. *Industr. Engng Chem.*, 1950, **42** (5), 850–5. (*116th Meeting Amer. Chem. Soc., Divn of Industr. Engng Chem.*)—Analysis is described of complex equilibria existing in any number of chemical species in a single gaseous phase. A gas combustion reaction at 40 atm pressure giving rise to ten gaseous constituents with or without formation of solid carbon is used to describe the principles of the method, which can be modified to allow for deviation from ideal behaviour due to pressure, temp, or concentration. Numerical solution of the working equations are described in several methods each applicable to typical types of equations. The equations, even for complex problems, can be rapidly set up for any equilibria by a routine procedure and are in a form readily soluble by subprofessional personnel. R. G. T.

1687. Adjustment of temperature scale of Cox charts. C. E. Rehberg. *Industr. Engng Chem.*, 1950, **42** (5), 829–30.—For a Cox chart drawn according to equation $y = at/(t + c)$ value of C used in preparing the temp scale can be adjusted as desired by adding or subtracting the appropriate number for each temperature on the scale. Thus for one type of paper, Cox chart can be adopted to give straight-line vapour–pressure–temp relations for any type of compound. This also represents an easy method of determining value of C in Antoine's equation $P = A - B(t + c)$.
R. G. T.

1688. Kinetics of reaction between methane and sulphur vapour. R. A. Fisher and J. M. Smith. *Industr. Engng Chem.*, 1950, **42** (4), 704–9.—Reaction between methane and sulphur to produce carbon disulphide is commercially important due to low cost of natural gas and sulphur. Experimental investigation of kinetics of the reaction are described. Temps between 550° and 625° C and varying reactant ratios and space velocities were used. A second-order reaction between methane and the S_2 species of sulphur is suggested on the assumption that rate of dissociation of S_8 and S_6 is faster than reaction with methane. Kinetic equations showing that S_8 or S_6 is the reactive species of sulphur vapour are not comparable with observed data. R. G. T.

1689. Kinetic studies in the chemistry of rubber and related materials. VII. Influence of chemical structure on the α-methylenic reactivity of olefins. J. L. Bolland. *Trans. Faraday Soc.*, 1950, **46**, 358–68.—Conclusions are drawn from a study of the radical reaction $RO_2^- + RH \longrightarrow RO_2H + R^-$ (representing exchange of a H atom between an α-group of an olefin RH and a peroxide radical RO_2^-) for twenty-four different

unsaturated hydrocarbons. In olefinic system $\underset{(a)}{CH_2}—\underset{(b)}{CH}=\underset{(c)}{CH_2}$ the α-methylenic reactivity of group (*a*) as measured by the above equation is: (1) increased by alkyl substitution at (*a*) and (*c*) by a factor $3{\cdot}3^n$ at 45° C where n = total number of alkyl groups introduced but unaffected by alkyl substitution at (*b*); (2) increased twenty-three-fold by phenyl substitution at (*a*); (3) increased 107-fold by an Alk. CH=CH– group at (*a*); and (4) increased 1·7 times greater for an α-group in a cyclic structure than in the analagous acyclic olefinic group. E. B.

1690. Kinetics of the photochemical gas-phase reactions between sulphur dioxide and *n*-butane and 1-butene respectively. F. S. Dainton and K. J. Ivin. *Trans. Faraday Soc.*, 1950, **46**, 382–94.—Results are given of a detailed investigation of the gas-phase photochemical (2400–3340 Å) reactions of SO_2 and *n*-butane and 1-butene respectively over the temp range 15–100° C. Mechanisms of the uninhibited *n*-butane reaction, the *n*-butane reaction inhibited by 1-butene or butadiene, and the 1-butene reaction are discussed. E. B.

1691. Spectroscopic studies of low-pressure flames. III. Effective rotational temperatures and excitation mechanism for C_2 bands. A. G. Gaydon and H. G. Wolfhard. *Proc. Roy. Soc. A*, 23.5.50, **201** (1067), 561–9.—Intensity measurements on the Swan bands of C_2 give effective rotational temperatures for a number of flames. Measurements at pressures of 1 atm and less are recorded for the following: acetylene/oxygen, acetylene/air, acetylene/nitrous oxide; methane/oxygen; benzene/oxygen; ethane/oxygen. For acetylene/oxygen at 1 atm the value is 4950° K, falling to 3800° K at 2 mm. For acetylene/air it is 3400° K at 1 atm, falling a little at low pressures. In discussing the excitation process, reasons are given against it being a true chemiluminescence. It is believed that the C_2 radicals are formed with high rotational energy and are electronically excited by collision with energy-rich molecules present in the flame and responsible for the high excitation temperatures previously recorded. These energy-rich molecules probably possess excess vibrational energy.

W. H. C.

1692. Spectroscopic studies of low-pressure flames. IV. Measurements of light yields for C_2 bands. A. G. Gaydon and H. G. Wolfhard. *Proc. Roy. Soc. A*, 23.5.50, **201** (1067), 570–85.—The light yield for the Swan bands has been measured for the following hydrocarbons: methane, acetylene, ethylene, ethane, propane, and benzene. For $C_2H_2 + 2\frac{1}{2}H_2O$ flames 3×10^{-5} photons are emitted for each O_2 consumed at 1 atm pressure, rising to $13{\cdot}5x^{-5}$ at 3·5 mm pressure. For propane the effect of pressure is more marked. The effect of mixture strength and of diluents is described. For partial replacement of hydrocarbon by H_2 or CO (the mixture being held stoichiometric) the yield falls with surprising rapidity, being proportional to a high power of the hydrocarbon concentration (square to sixth power). Preliminary results for CH are similar. The C_2 emission does not appear to be due to true chemiluminescence, but there is abnormally high excitation by some active species in the flame, and the concentration of C_2 exceeds the values found by Brewer, Gilles, and Jenkins for equilibrium with solid carbon at the flame temperature. Polymerization and formation of unsaturated compounds appear to be important. The relation between C_2 emission and the formation of solid carbon is discussed; polymerization of C_2 cannot account quantitatively for the formation of solid particles. W. H. C.

1693. Excitation of OH spectrum in flames at low pressures. A. G. Gaydon and H. G. Wolfhard. *Rev. Inst. franç. Pétrole*, 1949, **4**, 405–17.—Emission and absorption spectra of OH radical have been examined in various flames at low pressure, effective rotational temp measured, and relative light yields compared. Flames examined were H_2/O_2, H_2/N_2O, C_2H_2/O_2, $C_2H_2 + H_2/O_2$, C_2H_2/N_2O, CH_4/O_2, $CH_4 + H_2/O_2$, and also the CO/O_2 flame, in which the persistent OH bands are found even after drying the gases. Experimental methods are described and results discussed. E. B.

1694. Stability of burner flames with propane–hydrogen mixtures. S. H. Reiter and C. C. Wright. *Industr. Engng Chem.*, 1950, **42** (4), 691–4.—Investigations on stability of flames of propane, hydrogen, and mixtures of these are described. Blow-off and

flash-back data, obtained in the laminar flow range with air-cooled burner tubes, are correlated in terms of velocity gradients at the burner wall. Effect of increase in H_2 concentration in H_2–propane mixture is not linear for both blow-off and flash-back.
R. G. T.

1695. Note on the rheological properties of elastoplastic materials. K. Goldsmith. *Brit. J. Appl. Phys.*, 1950, **1**, 107.—The flow properties of some elastoplastic materials, such as certain gels and pastes, can be expressed by an empirical equation if the materials are subjected to a varying stress which is dependent on the shear. Three constants, derived from this equation, serve to characterize the flow properties. The work discussed is limited to soap gels and chalk pastes, but the results may apply to other materials which exhibit appreciable non-linear flow characteristics.
C. N. T.

Analysis and Testing.

1696. Progress review No. 8, sampling, analysis, and testing of solid, liquid, and gaseous fuels. A. H. Edwards. *J. Inst. Fuel*, 1950, **23**, 152.—A review of the literature published during 1948–49 is presented. The article is divided into standard methods, solid fuels, liquid fuels, and gaseous fuels.

Kramers and McKee propose the term "air-equilibriated moisture" to replace "air dried moisture." Hancock and Thornton's rapid methods of ash determination are briefly described. B.C.R.A. advocate either the Eschka method or a new high-temperature combustion method for the determination of sulphur in coke and coal. Kreulen–Van Selms and Kreulen show that a non-linear relationship exists between volatile-matter content and C.A.B. for anthracites and lean coal. A semi-micro method for the exhaustive solvent-extraction of coal with pyridine and chloroform has been developed to study the effect of carbonization and oxidation on the α, β, and γ fractions. Dryden found that anhydrous ethylene diamine is possibly a more powerful solvent for bituminous coal than pyridine.

Testing and specifications for fuel oils, determination of sulphur in liquid fuels, and fuels for gas turbines are considered.

An apparatus devised by Gooderham for analysis of coal gas, flue gas, and certain industrial gases is described. Moisture, carbon dioxide, carbon monoxide, oxygen and sulphur determinations, calorific value, and flue gas, are also discussed. There are fifty-eight literature references. D. K.

1697. Acid-base determinations of petroleum products. H. P. Ferguson. *Anal. Chem.*, 1950, **22**, 289–94.—For determining the acidic and basic characteristics of petroleum products it has been shown that single-phase rather than two-phase equilibrium titration methods are preferable. J. S.

1698. Petroleum. H. Levin. *Anal. Chem.*, 1950, **22**, 240–5.—The present review of progress in analysis in the field of petroleum takes into consideration the literature published during the year 1949. 140 references. J. S.

1699. Determination of bromine and chlorine in gasoline. B. Pecherer, C. M. Gambrill, and G. W. Wilcox. *Anal. Chem.*, 1950, **22**, 311–15.—For the determination of bromine and chlorine in gasoline disodium biphenyl was found to be an effective reagent for decomposing the ethylene halides present. The reagent can be prepared in ethylene glycol dimethyl ether or in tetra-ethylene glycol dimethyl ether. A sample of the gasoline to be analysed is diluted with benzene and treated with an excess of 0·5N solution of disodium biphenyl. After 30 minutes the excess of the reagent is decomposed with water, the alkali formed is neutralized, and the sodium halides extracted from the organic phase with water. The halides are determined by a potentiometric titration method. Tetra-ethyl lead does not interfere. The method gives results with an accuracy of $\pm$ 2% of the actual bromine and chlorine contents. J. S.

1700. Determination of liquid-vapour equilibria. New dew point, bubble point apparatus. M. Filler and H. J. McDonald. *Anal. Chem.*, 1950, **22**, 338–40.—A new form of dew point–bubble point apparatus is suitable for determining the liq–vapour equilibria of

binary systems which are liq at room temp and atm pressure. The technique of operation and the theory and method of deriving both the individual dew points and bubble points and the total dew-point curve and bubble-point curve are given. The method is advantageous because only small amounts of reagents are needed for the complete determination of a system, and no analyses are required. Applications of the apparatus are in determination of molecular weights of liquids, analysis of binary liquid systems, and the study of liq–vapour equilibria of ternary and higher systems.
J. S.

1701. Determination of total phosphorus in organic compound. W. R. Simmons and J. H. Robertson. *Anal. Chem.*, 1950, **22**, 294–6.—Two procedures are described for the conversion of organic phosphorus in insecticides into the ionized orthophosphate, the phosphorus being determined colorimetrically by the molybdivanadophosphate–alkimetric method. One procedure is based upon the reaction with hydriodic acid; the other is based upon destructive oxidation with a mixture of nitric, perchloric, and sulphuric acid in the presence of sodium molybdate as a catalyst. J. S.

1702. Chromatography of gases and vapours. C. S. G. Phillips. *Faraday Soc. Discussions*, 1949, **7**, 241–8.—Gases or vapours are brought on to an adsorbent column in a carrier gas and subsequently displaced by the carrier gas saturated with the vapour of a desorbent. The step-height (% desorbent) measured by a self-recording thermal conductivity cell is const and characteristic of any particular component desorbed and step-length (time for displacement) is $\propto$ the amount of component present. Factors influencing the accuracy of analysis are discussed, *e.g.*, particle size, flow rate, column design, type of adsorbent, temp, and nature of mixture. Activated charcoals are used with N_2 as carrier gas and ethyl acetate as desorbent. Examples illustrated include the separation of hydrocarbon gases. E. B.

1703. Vapor–adsorbate equilibrium. I. Propane–propylene on activated carbon and on silica gel. W. K. Lewis, E. R. Gilliland, B. Chertow, and W. H. Hoffman. *J. Amer. chem. Soc.*, 1950, **72**, 1153–7.—The adsorption isotherms of propane and of propylene were determined at 25° ± 0·1° C on activated carbon and on silica gel. This was followed by an examination of the equilibrium behaviour of binary mixtures of these two physically similar gases over each of the adsorbents at the same temperature. The adsorption capacity per unit weight of carbon is greater for these hydrocarbons than that of silica gel, but carbon does not differentiate greatly between them, whereas silica gel does; propylene becoming much less volatile than propane. All adsorptions were reversible, and recovery of the adsorbate was substantially complete.
W. H. A.

1704. Vapor–adsorbate equilibrium. II. Acetylene–ethylene on activated carbon and on silica gel. W. K. Lewis, E. R. Gilliland, B. Chertow, and W. Milliken. *J. Amer. chem. Soc.*, 1950, **72**, 1157–9.—Adsorption isotherms of acetylene and of ethylene on activated carbon and on silica gel have been determined at 25° ± 0·1° C. Examination of the equilibrium behaviour of mixtures of the two gases over each of the adsorbents showed that carbon had a greater capacity for each of the hydrocarbons than had silica gel and that acetylene is more volatile than ethylene over carbon and is the less-volatile component over silica gel, which is more discriminating than carbon. All the adsorptions were reversible. W. H. A.

1705. Vapor–adsorbate equilibrium. III. The effect of temperature on the binary systems ethylene–propane, ethylene–propylene over silica gel. W. K. Lewis, E. R. Gilliland, B. Chertow, and D. Bareis. *J. Amer. chem. Soc.*, 1950, **72**, 1160–3.—Adsorption isotherms for each of the hydrocarbons over silica gel have been determined at 0°, 25°, and 40° C. Equilibrium behaviour for the systems ethylene–propane and ethylene–propylene at 0°, 25°, and 40° showed that ethylene is relatively more volatile than propane or propylene in the binary systems and that it exhibits a much greater relative volatility in the propylene system than in the propane system. All the adsorptions were reversible. W. H. A.

1706. Composition of synthetic liquid fuels. I. Product distribution and analysis of C_5–C_8 paraffin isomers from cobalt catalyst. R. A. Friedel and R. B. Anderson. *J. Amer. chem. Soc.*, 1950, **72**, 1212–15.—The distribution of hydrocarbons in a Fischer–Tropsch synthesis fuel obtained by reacting 2 hydrogen to 1 carbon monoxide in the presence of a precipitated cobalt catalyst at 190° and atmospheric pressure has been determined. It shows a large yield of methane and a min of C_2 hydrocarbons followed by a broad max from C_5 to C_{11} with a gradual decrease to C_{20}: 10% of the product was above C_{20}, and oxygenated compounds were present in all fractions. An aliquot of the distillate from the liquid product was percolated through a silica-gel column to quantitatively separate paraffins, olefins, and oxygenated plus other residual material. The paraffins obtained were fractionally distilled into C_5–C_8 molecular weights and analysed for isomers using a mass spectrometer. The predominant components were straight-chain hydrocarbons which decreased with increasing molecular weight. The only branch-chain members present were the mono-methyl isomers. Analysis of the olefin fraction showed that internal double-bond olefins were the major constituent and that the *trans* form were in greater concentration than the *cis*. W. H. A.

1707. French mass spectrometer for the petroleum industry. I. Main characteristics of the C.S.F.-I.F.P. mass spectrometer. T. Reis, F. Bertein, J. Vastel, J. Buzon, and F. Nief. *Rev. Inst. franç. Pétrole*, 1950, **5**, 59–76.—General principles of mass spectrometry are briefly considered, and a mass spectrometer built under auspices of the I.F.P. is described in detail. Spectra are recorded photographically, and the instrument has a resolving power of 1/150. Standardization and operational technique are described. Thirty-two references. V. B.

1708. French mass spectrometer for the petroleum industry. II. Application of mass spectrometry to analytical problems. T. Reis, J. Buzon, and G. Nief. *Rev. Inst. franç. Pétrole*, 1950, **5**, 91–103.—Applications to hydrocarbon analysis and also for the examination of compounds containing O and S are discussed. Other possible uses of mass spectrometry are the detection of very small amounts of gas and the study of the kinetics of chain reactions. With the I.F.P. apparatus and using operators on shift a total of 500 analyses/month should be attainable. Eighty-three references. V. B.

1709. New methods for the determination of molecular weight by vapor density. W. H. Eberhardt. *Chem. Education*, May 1950, **27** (5), 248.—Whenever simultaneous measurements of the pressure, temp, and density of a gas can be made in any experiment, that experiment may be used with the aid of some equation of state for determination of the molecular weight of the gas. A technique is outlined by which two methods for obtaining these data may be investigated concurrently, and conditions are such that the ideal gas laws may be used with good accuracy for the calculation. A method known as the total mass–total volume determination of gas density is first described, and this depends on the fact that if the volume of a system is known and a known weight of sample is introduced and vaporized into the volume, the gas density may be computed immediately. The direct determination of gas density using a density balance is then described and illustrated, and a schematic diagram of the apparatus used is included. A table is given showing data obtained by both techniques using carbon tetrachloride. The results demonstrate that the two techniques are of comparable precision, about 1%. A. S.

1710. Vapour pressure of Otto [cycle] engine fuels. Swiss Standards Ass. *Schweiz. Arch. Ang. Wiss. Tech.*, 1950, **16**, 125–8.—Draft Swiss standard (SNV 81108) for this test is given in full. Method is essentially similar to I.P. 69/45 except that dimensions of apparatus are considerably smaller, although vol ratio air chamber/gasoline chamber is unaltered. Sampling and sample-transfer technique is not specified as rigidly as in I.P. method. V. B.

1711. Significance of properties of petroleum products. X. Engine testing of lubricants. J. Atkinson. *I.P. Review*, 1950, **4**, 127.—The Co-ordinating Research Council, U.S.A., formed by the American Petroleum Institute and the S.A.E., has published a series of engine-oil test procedures, but in Britain similar test conditions

are not yet standardized. The designation of these C.R.C. tests and the properties they evaluate are enumerated. Certain aspects of oil performance such as wear, bearing corrosion, and deposit formation can be measured quantitatively, others qualitatively by comparison with standards. Necessity for control over fuel quality, as well as over preparation and operation of test engines, for evaluation of oil performance is stressed. Ring-sticking tests are of two types, variable duration, where oil performance is expressed in terms of test duration necessary to cause ring sticking, and constant duration, where cylinder-barrel temperature required to cause ring sticking in fixed time is criterion of oil performance. Diesel lubricants should have property of " detergency," which prevents soot from restricting ring movement. The types of wear recognized are abrasive, caused chiefly by dust-laden atmosphere, and corrosive, caused by acids formed during combustion. Relative merits of different oils can be compared by extent to which each is capable of preventing or delaying onset of corrosion. Tests to evaluate corrosive wear can also be used to assess crankcase corrosion and low-temperature sludging. Bearing corrosion tests are usually carried out on copper–lead bearings. Performance is assessed in terms of weight lost per whole bearing for a given temperature and duration of test. Comments are given on the significance of oil tests, when each type of test evaluates the performance of oils only under the particular operating conditions used, and does not necessarily predict field performance. A bibliography of seventeen references is included.

U. N.

1712. Computation of the viscosity of the mixtures of oils. H. Gorka. *Nafta*, Mar. 1949, **5**, 61–2.—Summarizes Roegiers's nomogram and briefly describes Roegiers's instrument for the determination of viscosity of a mixture and for intramolecular attraction α. The instrument consists of a triangle, a slide-rule, and a protractor. Formulæ are given :—

$$\eta_{1x} = \eta_{i2} \frac{x\alpha}{\frac{\eta_{i1}}{\eta_{i2}} x\alpha + (100 - x)}$$

$$\alpha = \frac{(100 - \xi)(\log \eta_{i\xi} - \log \eta_{i2})}{\xi(\log \eta_{i1} - \log \eta_{i\xi})}$$

where η_i = vis in cp ; ξ and x = ratio or percentage of components ; and α = attraction in ergs.

M. S.

1713. A cone and plate viscometer. R. S. Higginbotham. *J. sci. Instrum.*, 1950, **27**, 139.—A novel and simple viscometer has been devised to determine the flow curves of anomalous fluids (*e.g.*, thixotropic pastes which are unstable to shear) over a wide range of rates of shear. It is easy to fill and clean, and has proved particularly useful for measurements at rates of shear of 10,000 sec^{-1} and upwards. The instrument was calibrated with liquid paraffin, and data given show that the ratio torque/speed is constant from 2 to 26 r.p.m., but decreases by about 3% between 26 and 185 r.p.m. This decrease may be partly due to heat generation within the fluid. A graph giving flow curves for typical anomalous systems is included.

C. N. T.

Crude Oil.

1714. Salts in crude oil. J. P. Hilfinger. *Rev. Inst. franç. Pétrole*, 1950, **5**, 153–5.—Previous views on the form in which salt is present in crude are briefly reviewed ; two theories exist, one that salt can occur in crude as finely dispersed crystals and the other that all salt found in crude is dissolved in emulsified water. The latter view is particularly strongly favoured by Benkovskii (*Neft. Khoz.*, 1946, (6), 44). Tests were made on five samples of Pechelbronn crude. Water separated from the crudes had a salt (NaCl) content of 40–130 g/l. Water salinity, water content of crude (a), and salt content of crude (b) were determined. Plot of (a) against (b) gave straight lines passing through the zero. In each case salinity of water remained const, being the same for settled water as for last traces of water removed centrifugally ; microscopic examination of crude failed to show salt crystals unless water had been removed by

evaporation. Views of Benkovskii (*loc. cit.*) that salt in crude is entirely present in aq phase are thus confirmed. V. B.

Engine Fuels.

1715. Future of British civil aircraft and their power units. F. R. Banks. *J.P. Review*, 1950, **4**, 118.—The development of British passenger aircraft, including the Brabazon, Lancastrian, York, Viking, Princess, Viscount, Apollo, Ambassador, Comet, and XC.102, is described, together with some details of their engines, power, range, etc. The noise level in propellor turbine and in jet-engined aircraft is compared. There is little or no noise from the exhaust of the propellor turbine because there is little energy left in the exhaust gases. In the pure jet the principal source of noise is the jet discharge itself. On the question of fuel requirements, it is hoped that there may be sufficient of the present aviation kerosine to meet future world civil aviation requirements when a large number of gas turbines are in use which do not need a gasoline-type fuel of high vapour pressure. For military purposes it may be necessary to use a fuel of somewhat higher vapour pressure than kerosine. The fuel-ignition problems of re-lighting gas turbines at altitude, and the importance of a long operating life between overhaul periods of both piston engines and gas turbines, are discussed. U. N.

1716. Fuel ignition in diesel engines. Influence of ethyl nitrate. O. Widmaier. *Rev. Inst. franç. Pétrole*, 1950, **5**, 140–7.—Methods of evaluating diesel fuels are compared. F.K.F.S. and I.G. procedures measure ignition delay, the first by time between fuel injection and ignition (detected photo-electrically through a quartz window), and the second by time between fuel injection and commencement of pressure rise, latter may, however, be due to oxidn reaction preceding ignition. In H.W.A. method a fixed C.R. is used and quantity of air is varied, thus varying pressure within cyl and hence temp at ignition. Whilst cetane No. can be determined by both types of procedure, results are not comparable, since first type of method evaluates ignition delay, whilst H.W.A. method measures startability. Definite proof of preliminary oxidn reactions has been obtained, using a paraffinic gas oil; such reactions are sufficiently intensive to rotate engine without actual ignition occurring. Ethyl nitrate added to fuel decreases delay angle, but does not appreciably affect startability. If, however, it is added to air, startability is greatly improved. Such addition to air may be either at air intake or by injection from a reservoir. For starting a 1-l-capacity single-cyl test engine 0·6 ml ethyl nitrate was required. Air pre-heating facilitates starting only for naphthenic or aromatic fuels. V. B.

Gas Oil and Fuel Oil.

1717. A graphical method for estimating fuel consumption for heating. G. P. Jankauskas. *Heating & Ventilating*, May 1950, **47** (5), 82.—A method is described for determining the fuel consumption for space heating over any period. It is based on relating degree-days to installed capacity. Installed capacity of a heating plant is based on design conditions, including an outside design temp set low enough to handle max probable demand. Fuel consumption is a function of outside conditions which may vary hourly. The number of degree-days which occur during a period is taken as a useful indication of actual outside conditions over that period. The development of equation for fuel-consumption estimation is shown, and this equation is plotted graphically in straight lines on a logarithmic scale. An example of the use of the fuel-estimating chart is given. A. S.

1718. Diesel fuel oil storage. Anon. *Gas Oil Pwr*, 1950, **45**, 78–80.—Since in the diesel engine fuel injectors and injection pumps have to meter accurately small quantities of fuel against high pressures, the equipment is manufactured to precision standards with fine clearances, and even microscopic particles in the fuel will cause damage. This article deals with precautions which should be taken by engine users to ensure that fuel is not contaminated. The following points are considered: (1) fuel should be obtained from a reputable source; (2) two tanks should be used, so that the contents of one can settle while the other is in use; (3) tank sizes and installation are discussed;

(4) ungalvanized materials must be used, and they must be thoroughly cleaned before installation; (5) draincocks, manholes, and vents must be provided; (6) the inlet pipe should be fitted with a strainer and terminate about 6 in from the tank bottom; (7) the outlet pipe should be 3 in from the tank bottom, and fitted at the upper end of the tank if the latter is slightly inclined; (8) sludge and water should be drawn off each week, and the tank cleaned at least annually.

Drum storage is not recommended.

Vehicle tanks and fittings should be cleaned periodically, and a felt or fabric filter should be used between fuel tank and injection pump. H. C. E.

Lubricants.

1719. Rate of lub. oil consumption in internal combustion engines. W. A. Tookey. *Gas Oil Pwr*, 1950, **45**, 84.—In installations using oil power for the generation of electricity and the pumping of water, the Diesel Engine Users Association uses for comparing working costs: (*a*) the ratio fuel oil/lub. oil; (*b*) the rated b.h.p. hr per gal of lub. oil. As regards (*a*), ninety-seven engines gave an average of 55 with max and min of 127 and 24; as regards (*b*), sixty-two stations gave a mean of 2160, but the max and min were 11,000 and 800. Neither of these calculations, therefore, gives a reasonable basis for comparisons.

All running engines need lub. oil whether developing power or not, and the amount required will depend upon the number and size of the pistons, and their r.p.m. It is pointed out that for all normal engines the product of cyl dia and r.p.m. is approx constant. Hence the oil consumption can be compared from engine to engine by evaluating the expression :—

$$\frac{\text{no. of pistons} \times \text{hours run}}{\text{gals of lub oil}} = C$$

In the case of four engines at the same station, $C = 19{\cdot}2 \pm 0{\cdot}3$. From the data given in the D.E.U.A. Report, $C = 28{\cdot}4$ for generating installations and 54 for pumping stations. It appears that small high-speed engines run for longer periods per gal lub. oil than do heavier engines. Also for overseas generating stations C is smaller than for elsewhere, indicating that ambient temperatures may have some influence. H. C. E.

1720. Phase behaviour of lithium stearate in cetane and in decalin. M. J. Vold and R. D. Vold. *J. Coll. Sci.*, 1950, **5**, 1–19.—The structure of fatty acid soaps in hydrocarbons is of importance in understanding the behaviour of greases. The systems lithium stearate (LiSt)/cetane and LiSt/decalin have been studied by visual observations and by differential thermal analysis over a complete range of soap concentrations and at temps up to 225° C. In both systems the following single phases were identified: two crystal forms of LiSt, a waxy phase, isotropic liquid, and non-aqueous middle soap. The phase diagram of LiSt/petroleum oil resembles that of the LiSt/cetane system, and phase-change temperatures for commercial lithium greases are given. The similarities and differences between cetane and decalin as solvents are explained in terms of the structure of the various phases. Some of the phenomena associated with the manufacture of lithium greases; *e.g.*, the high temperature necessary to disperse lithium soaps in oil, and the bleeding of concentrates containing more than 40% soap, can be explained from a knowledge of the phase diagrams. H. C. E.

1721. Behaviour of contemporary lubricating oils in French engines. A. Schilling. *Bull. Ass. franç. Tech. Pétrole*, 1950, (81), 3–28.—A lecture, describing work carried out during the last two years by the I.F.P. at the Claude Bonnier national research establishment. Principal engines used for test purposes are a 11 h.p. Citroen and a 4 h.p. Renault, both these being examples of mass-produced designs. Conditions are more severe in the smaller engine. Other (single-cyl) engines, including diesel, are also available. Test bench lay-out is shown and test conditions outlined, 50-hr tests (in 10- and 12-hr periods) are most used. Demerit rating is used for assessing condition of engine parts, pistons are photographed for record purposes. It is considered that normal inspection tests give little information as to the condition of a used oil,

and a test is described wherein a solution of used oil in kerosine is poured through folded filter-paper; oil is rated by depth of penetration coupled with opacity (measured photo-electrically) of successive stains. Non-detergent oils show high opacity at first which tails off rapidly, stains from detergent oils are more uniform. Measurement of Fe content of oil and oil attack on Pb films are also used. Engine tests were carried out on base oils, finished French and imported lub. oils and on various additives; a total of twenty-six lubricants (inspections given) being examined. Results are tabulated and discussed. Tests were also made using a high S (1·1%) gas oil with low (45° C) coolant exit temp. Indications are that wear after 60 hr at 45° C is equivalent to that at 100° C for 100 hr. Wear with high S fuels can be considerably reduced by suitable additives. Conclusions are that naphthene base oils are more suitable than paraffinic for C.I. engines; additives improve engine cleanliness, but give rise to more carbon. Paraffin-base oils are the more sensitive to oxidn and corrosion inhibitors, which are more effective for spark-ignition engines, whereas detergent additives are of more value in C.I. engines. Additive/oil incompatibility is more probable with oxidn inhibitors than with other types of additive. Doped oils do not increase drain periods, although engine cleanliness is maintained; flushing is still recommended to remove spent oil and additive. V. B.

1722. New methods for the improvement of lubricating oils. J. Michalowska. *Nafta*, Jan.–Feb. 1949, **5**, 24–8.—The author reviews the ideal beneficial results of additives and considers how far the actual compounds in use satisfy the demands made upon them. Their other properties are also reviewed. Paraflow, Santopour, and Elektrion R are mentioned for lowering the pour point, Exanol, Paratone, and Uniflow for raising the V.I. as well as the Oppanol produced by Germany by polymerization of *iso*butylene. Amongst antioxidants the process for the Inhibitor R made by Germany is given. Against E.P. the Germans used Mesulfol 2, and the Dutch Me-di-β-naphthol and other epols. As anticorrosives soaps, detergents, and the German K.S.E.

$$(R\text{–}CH_2\cdot SO_3\cdot NH\cdot CH_2\cdot COOR')$$

are mentioned.

Fillers and oiliness carriers are also mentioned in the article. M. S.

Bitumen, Asphalt, and Tar.

1723. Determination of the viscosities and specific gravities of the oils in samples of Athabaska bituminous sands. S. H. Ward and K. A. Clark. *Research Council Alberta. Rept. No.* 57, Mar. 1950.—The difficulty of making visc and sp. gr. determinations on the oil in Athabaska bituminous sand is that there is no method available for getting the oil out of sand without altering it. A method of extracting the oil from the bituminous sand in a standardized, reproducible way and of correcting the visc and sp. gr. measurements on the recovered oil for the alteration of it that has taken place has been devised. The visc–temp relationships for the oils from several bituminous sands from locations widely separated over the bituminous sand area and from several beds at different elevations at Bitumount have been determined. Also, a relationship between the visc of a bituminous sand oil at 84·4° F and its sp. gr. at 77° F/77° F has been established. Results show that at 50° F, which is about the temp of bituminous sand beds at the fresh face of a quarry, the visc of the oil in the southern part of the bituminous sand area in the neighbourhood of McMurray is 100 times that of the oil in the northern part around Bitumount. The visc varies considerably from bed to bed throughout the 60 gravities, 77° F/77° F of bituminous sand oils examined over the range 1·002–1·027. (Authors' Abstract.)

Special Hydrocarbon Products.

1724. Mineral insulating oils in electrical engineering. H. Weiss. *Bull. Ass. franç. Tech. Pétrole*, 1950, (81), 29–46.—Lecture, dealing with use of oils in cables and condensers, switches, transformers. Electrical conductivity of oils is briefly considered, owing to polarization conductivity can, in a few hr, drop to $\frac{1}{10}$th of initial val. Cable nd condenser oils should have a power factor (tan δ) of the order of 10^{-4} at 100° C; hilst oxidn stability is desirable, oxidn is not a major influence in sealed equipment.

In oil-filled switches it is important to have adequate expansion space over the oil surface; used transformer oil is frequently employed in switches. O_2-absorption curves are given for transformer oils of varying degrees of refining, and the distribution of O_2 among the oxidn products is shown. Sludge is the most troublesome oxidn product (for transformer oils), yet it contains only 2–9% of the O_2 absorbed by oil, hence prediction of sludge-forming tendency from laboratory oxidn tests is difficult. Various ageing tests are compared, the conditions under which sludge formed is pptd are of vital importance, a ratio of as much as 60/1 between sludge values found on the same oil by various precipitation methods being possible. O_2 absorption tests are of value, but to evaluate an oil adequately the test must be prolonged till actual sludge formation occurs. Evaluation of inhibited oils is a separate problem for which more data is at present required. V. B.

Derived Chemical Products.

1725. Synthetic detergents vs. soap for industrial purposes. J. W. McCutcheon and F. D. Snell. *Soap Sanitary Chem.*, Feb. 1950, **26**, (2), 44.—This article describes a debate in which the arguments put forward in favour of synthetic detergents were based on their stability in acid solutions, the non-precipitation of their calcium salts in hard water, their wide range of application, since they can be anionic, cationic, or non-ionic, and finally their low retail price.

In answer to these contentions it was argued that soap has a much superior action in softened waters, which are widely used, particularly for domestic purposes, and also has no deleterious effects on human skin, has superior surface activity giving better detergency and better lather, and can be made at a lower cost. In connexion with the claim that synthetic detergents are sold at a lower price, it was pointed out that many of these preparations contain only very small amounts of active material. O. M.

Coal, Shale, and Peat.

1726. Recent research on coal. C. Ellis. *Nature*, 1950, **165**, 583–5.—Research on the structure of coal is undertaken in order to classify coals on a basis involving three or four fundamental properties. Thus the C/H ratio for all coals falls within a fairly narrow range. It has also been found that coals have a porous structure which is believed to arise by aggregation of polymers or micelles held together by van der Waals forces. X-ray measurements indicate that these aggregations have mol. wts. greater than 4000. The pyridine extract of coals contains crystallites of the same range, but mild hydrogenation and fractionation conditions produce bodies of mol. wt. 400–2000. The coking power of some coals can be explained in terms of plasticity of the coal accompanied by chemical breakdown of the polymers as the temperature is raised. Mineral matter in coal may be obtained from plant structure (vitrains) or clays, etc. (durains), and the manner in which it is associated with the polymer may throw more light on the constitution of coal. H. C. E.

1727. Application of the Reynolds analogy to combustion of solid fuels. R. S. Silver. *Nature*, 1950, **165**, 725.—The Reynolds analogy between heat transfer and friction in the flow of fluids can be expressed in the form :—

$$f = 2h/\rho c_p v$$

where f and h are the friction and heat-transfer coeffs, ρ and v are the density and mass velocity of the fluid, and c_p its sp. ht. (at constant pressure if a gas).

When the temp during the combustion of solid fuels is sufficiently high the rate at which oxygen can be transported to the surface becomes the governing factor. Then the Reynolds analogy can be extended and, with air as fluid, carbon as solid fuel, and CO_2 as the product, it can be shown that the reaction rate $R = 0{\cdot}0875h/c_p$ or $0{\cdot}0875\rho vf/2$. For air, $h/c_p \sim 10^{-3}$ g/sec/cm^2, giving $R \sim 10^{-4}$ g/sec/cm^2, which is the magnitude found experimentally. The equations can be used for finding variations in combustion rate under different conditions across fuel beds, although if these are thick the problem is complicated by the formation of CO as an intermediate product. H. C. E.

Miscellaneous Products.

1728. Recent developments in high-temperature refractory materials. A. E. Dodd. *J. Inst. Fuel*, 1950, **23**, 144.—The work of Clews and Green on silica and sillimanite insulating refractories is discussed. A kyanite–topaz light-weight brick has been made in the U.S.A. It has a porosity of 55%, low shrinkage at 1600° C, and good load-bearing properties at 1450° C.

The X-ray pattern of MgO is fundamentally the same whatever the crystal size or apparent density. This shows by inference that the properties of pure magnesia refractories must be greatly influenced by periclase (*i.e.*, the crystalline MgO). Results obtained by Colegrave, Richardson, and Rigby on the increase in crystal size with increased firing temperature are shown in figures, the influence of iron oxide on the crystal growth is also shown. A test piece made from fused magnesia 98% pure fired at 1775° C, showed negligible contraction when heated for 1 hr at 2300° C. This strongly pre-fused magnesia shows exceptional refractoriness-under-load. For some purposes a disadvantage of magnesia as a refractory is its high thermal expansion, since this is one cause of low resistance to spalling.

Fused alumina, Ryschketwitsch's work on the firing shrinkage of alumina, and results obtained are discussed. The strength of fused alumina is high at room temperature, but falls rapidly at high temperatures, in spite of this it has valuable properties. An equation is deduced showing factors on which resistance to spalling is dependent.

The effect of high temperatures on the crystal structure of zirconia, and the effect of additions (CaO, MgO, Y_2O_3) on the expansion of zirconia, are discussed.

As a refractory zircon shows excellent resistance to attack by coal ash and molten aluminium.

Owing to uniform and moderate thermal expansion and its high thermal conductivity beryllia has very good resistance to thermal shock. Many tables of data on the refractories discussed are included. There are seventeen literature references.

D. K.

1729. Chlorinated hydrocarbons. W. A. Gersdorff, R. H. Nelson, and N. Mittin. *Soap Sanitary Chem.*, Apr. 1950, **26** (4), 137.—The chlorinated hydrocarbons heptachlor, aldrin, and dieldrin, derivatives of indene and naphthalene, and similar in nature to chlordane, have been investigated as insecticides in comparison with chlordane, using the Campbell turntable method on laboratory-reared adult house-flies. It was confirmed that heptachlor and aldrin are about five times as toxic as technical chlordane and that dieldrin is about twice as toxic as aldrin. None of the sprays made with the chlorinated compounds caused appreciable knockdown. O. M.

1730. Paint industry in Germany during the period 1939–1945. B.I.O.S. Report No. 22. II. Water paints. III. Cellulose lacquers. IV. Linoleum and coated fabrics. N. Fisk and H. W. Bowron. *Paint Technol.*, May 1950, **15** (173), 211.—The article is concluded from *Paint Technol.*, Apr. 1950 (Abstract No. 1570). German work on water paints, emulsifying agents, etc., cellulose derivatives, plasticizers, solvents, linoleum, and coated fabrics is described. D. K.

Corrosion.

1731. Underground corrosion of pipelines. Anon. *Times Rev. Ind.*, 1950, June 20–2.—Soil corrosion sub-committee of the British Iron and Steel Research Association has recently been formed to study corrosion problems affecting the 100,000 miles of water-main in Great Britain. In extreme cases pipe perforation can occur in a year; neutral water-logged clays are the most dangerous soils. Most severe corrosion is due to desulphurizing bacteria which are active in anærobic conditions. British water-mains are usually spun iron with a thin hot-dip tar coating, which is inadequate to give protection. Laying of pipe in a sand, gravel, or chalk surround favours ærobic conditions which combat corrosion. Concrete coating can be used, but should be 3 in thick; if bitumen is used thickness should be $\frac{1}{8}$–$\frac{1}{4}$ in. Glass wrappings are a recent

development, and are preferable to cellulosic material such as hessian. Cathodic protection has given excellent results, Mg and Al anodes appear to be most suitable. Using a heavy coating and cathodic protection initial protection cost is approx 5*s*. per yd. Belgian experience with cathodic protection indicates that cost can be as low as 0·1% per annum of pipe value. A protection expenditure as high as 30% of pipe-structure cost can, however, be permissible. Sixteen references. V. B.

Engines and Automotive Equipment.

1732. Jet installation design problems. Symposium by a panel of experts. Anon. *Aero. Engng Review*, Apr. 1950, **9** (4), 28.—Report of a symposium given at the Annual Meeting, Institute of Aeronautical Sciences, New York, in January 1950. A panel of speakers presented the points of view of the aircraft designers and the engine manufacturers on the basic problems in turbojet installations, both from the aspect of fuselage installations and the systems and accessories essential to keep the aeroplane and engine in operation. U. N.

1733. Ceramics in gas turbines. Anon. *Mech. World*, 26.5.50, **127** (3306), 584.—Several ceramic bodies which will presently become available might have adequate properties to permit increases in the operating temp or stress, or both, on present rotor blades. However, all of these bodies are non-ductile, and mechanical shock and stress concentrations are expected to present critical problems in their use. In addition to brittleness some of the bodies also have serious thermal-stress limitations, and max performance of rotor blades made from these materials will therefore depend on design and operational adjustments to counteract this brittleness. Close co-operation between ceramists and gas-turbine engineers will therefore be essential. Considerable amount of ceramic research is also being directed towards developing and evaluating refractory ceramic coatings for metals. The primary purpose of the coatings is to seal metal surface against corrosive attack, and secondarily to provide thermal insulation, although not much can be expected as far as the latter is concerned, as they must be thin in order to be tough and adherent. In general, rapid advances have been made during past few years in ceramic research, relevant to gas turbines. However, there are still many uninvestigated raw materials and combinations of raw materials from which better gas-turbine components might be made. A. S.

1734. Marine gas-turbine research in Britain. T. W. F. Brown. *Mech. Engng*, May 1950, **72** (5), 379.—The paper divides the research on gas turbines in Britain into : (*a*) government research establishments and government contracts and firms, (*b*) research associations, (*c*) research carried out by private firms. These organizations are described separately, the first group being divided into the principal government departments dealing with problems of gas-turbine work. The question of gas turbines for marine purposes is dealt with in detail, and it is shown that of all the marine gas turbines under construction in Britain, the most important units are being constructed to Admiralty order. Comparisons are made of weights and performances of various types of merchant-ship propulsion machinery, and drawings are given of the lay-out of the 3500-s.h.p. Parsons and Marine Engineering Turbine Research and Development Association (Pametrada) gas-turbine propulsion unit. Further comparisons are made of gas-turbine units with direct-coupled oil-engine and steam-turbine sets, and the main problems to be elucidated in the development of the gas turbine are discussed. Indications are given of present and future trends—gas-turbine components and future gas-turbine designs. A. S.

1735. New Petter–Fielding engine. Anon. *Gas Oil Pwr*, 1950, **45**, 90.—This D.H. model is a single-cylinder cold-starting horizontal four-stroke oil-engine developing 13–16 b.h.p. at 650–800 r.p.m. and intended for mobile pumping and generating sets. The bore and stroke are 142 and 200 mm, and the fuel consumption at max b.h.p., corresponding to a b.m.e.p. of 82 p.s.i., is 0·39 lb per b.h.p.hr.

The fuel is fed by a Bryce pump through a Bryce four-hole injector into the toroidal combustion chamber in the piston crown. A chamber below the fuel-pump collects

any surplus fuel, and thereby prevents dilution of the lub. oil. Lubrication is via a plunger-type pump to the main bearings, connecting-rod bearings, and the camshaft and governor. The pressure of 20 p.s.i. is controlled through a spring-loaded relief valve. The cylinder-liner and rings are splash-lubricated.

Details of the engine construction and auxiliary equipment are given. H. C. E.

1736. Gardner L.W. type automotive engine. Anon. *Gas Oil Pwr*, 1950, **45**, 92–6.—This direct-injection four-stroke type has from four to eight cyls of dimensions 4¼ and 6 in, and develops 68–140 b.h.p. at 1700 r.p.m.

Detailed descriptions are given of the engine construction, fuel-injection arrangements, lub.-oil system, and auxiliary equipment. The performances of the four engines of four, five, six, and eight cylinders are given graphically by plotting torque, b.h.p., and fuel consumption each against r.p.m.

The article is illustrated by five diagrams. H. C. E.

1737. New Leyland–M.C.W. Olympic bus. Anon. *Gas Oil Pwr*, 1950, **45**, 49.—The construction of the chassis and body, which are of integral construction, is described.

The power unit is a Leyland six-cyl direct-injection oil-engine with cylinders of 4·8 in bore and 5·5 in stroke, developing 125 b.h.p. at 1800 r.p.m. The C.R. is 15·75 : 1. The engine is horizontally disposed under the floor of the bus, together with the clutch and gear-box. Lub. oil is delivered to the engine by a gear-type pump driven from the camshaft, and full oil pressure is supplied to the big-end and camshaft bearings. Fuel is supplied by a C.A.V. fuel-pump through a multi-hole injector. Engine-cooling water is circulated through the cylinder-head and block by a centrifugal pump and returned through a stack-type cooling radiator. H. C. E.

1738. Dutch spark-fired gas engine. Anon. *Gas Oil Pwr*, 1950, **45**, 75–7.—Intended for use in oilfields and refineries, these Vee engines are designed as single units with compressors. The engines run on natural gas and have eight or ten cyls of bore and stroke 11·81 and 14·17 in respectively, giving an output of 50 b.h.p. per cyl at 400 r.p.m. with a b.m.e.p. of 65·4 p.s.i.

The diameter of the compressor cyls is such that the full engine output is utilized, and the unit is so arranged that two gas cyls drive one compressor cyl, all the connecting-rods being attached to the same crank.

Details of the engine design are described, including the operation of hydraulic tappets which are introduced because the valves are not easily accessible for adjustment.

Pressure lubrication is employed throughout, but since a special lub. oil is used in the compressor a separate system is fitted for this cyl. A special device which stops the engine if the lub.-oil pressure falls too low is incorporated, and another safety device short-circuits the magnetos if the cooling-water temp rises above 90° C.

Seven diagrams illustrate the article. H. C. E.

1739. Paxman RPHL and RPHXL engines. Anon. *Gas Oil Pwr*, 1950, **45**, 71–5.—These engines are designed for main-line rail traction, as units of six, twelve, or sixteen cyl giving a power output of 250–1000 b.h.p. The twelve- and sixteen-cyl units are turbo pressure-charged. The bore and stroke are 7 and 7½ in respectively, and the max continuous rating is 1250 r.p.m.

Constructional details of the crankcase, cyl block, cyl head, valves, and crankshaft are described.

The combustion chamber is of the Richardo Comet type, and a C.A.V. fuel-ignition-injection pump, with six or eight elements and a totally enclosed camshaft, is employed. The Al-alloy pistons are fitted with three pressure and two scraper rings.

The Paxman hydraulic governor is operated by remote control, and is arranged to stop the engine if the oil pressure fails. Forced lubrication at 70 p.s.i. is employed throughout.

Low-pressure warning switches in the lub.-oil and cooling systems, and alarms which operate if a turbo-charger fails are installed. Warning is also given of excessive temps.

Seven diagrams and drawings illustrate the article. H. C. E.

1740. More power from R4AU National engine. Anon. *Gas Oil Pwr*, 1950, **45**, 81–3.—Tests are described on the R4AU8 pressure-charged unit running at 600 r.p.m. Results of the tests are given by the following curves : (*a*) air-delivery curve ; (*b*) cyl diagram on a piston-stroke basis and on a crank-angle basis ; (*c*) cyl and exhaust-manifold pressures diagram ; (*d*) fuel consumption, exhaust temp, supercharging pressure, and air temp against b.m.e.p. (See also Abs. No. 1619, 1949.) H. C. E.

1741. Special service locomotive. Anon. *Gas Oil Pwr*, 1950, **45**, 100.—Designed for use over a hilly route in Bolivia, this diesel-electric locomotive is powered by a Sulzer six-cyl pressure-charged engine of cyl dimensions 11 in bore and 14½ in stroke. At 750 r.p.m. it develops 915 and 730 b.h.p.hr. at sea-level and 13,000 ft (where it will operate) respectively. The oil and fuel consumptions are 3·55 lb/hr and less than 174 g/b.h.p.hr. respectively.

The power is transmitted to main and auxiliary generators, and thence to two force-ventilated traction motors. The locomotive weighs 69·3 tons, and provides a max starting effort of 33,000 lb and a continuous rated tractive effort of 16,750 lb at 10·25 m.p.h. H. C. E.

1742. Crankshaft bearing failures. P. H. Smith. *Gas Oil Pwr*, 1950, **45**, 35–7.—It has been found that a graph of oil pressure versus piston speed can be constructed such that bearing failures occur in the region below the line and satisfactory operation is obtained at points on the line.

Stages in the disintegration of a white-metal bearing are described, and some methods designed to lengthen its life are indicated. Improvement was only obtained by increasing the oil pressure, but the full effect is not obtained until the flow of oil is increased beyond that corresponding to the increased pressure. Thus the ideal bearing floats in oil at high pressure. H. C. E.

1743. Balanced-pressure engine indicator. D. L. Church and D. K. Hart. *Mech. Engng*, May 1950, **72** (5), 389.—The balanced pressure indicator is an instrument for obtaining indicator cards on reciprocating engines, compressors, pumps, and the like. The system consists of a pick-up transducer containing a diaphragm exposed to the engine-cylinder pressure (or manifold pressure) on one side and an applied calibrated pressure on the other. When the cylinder pressure exceeds the applied pressure, the diaphragm deforms to close an electrical circuit. Likewise, when the cylinder pressure diminishes the circuit is broken. An electrical circuit converts the resulting pulses into a visible trace by inducing a spark through spark-sensitive paper each time the diaphragm makes or breaks contact. A stylus which comprises one side of a spark gap is mounted on or actuated by a pressure-sensitive servo (piston-cylinder or Bourdon Tube arrangement) which is motivated by the same calibrated pressure as applied to the pick-up transducer. The stylus moves adjacent and parallel to a drum on which the sensitive paper is wrapped, the drum being coupled to the engine shaft to run at the same speed and in accurate index to the engine. Provisions are also made for obtaining top-dead-centre and constant-pressure lines on the diagram. A circuit diagram is given, and this is discussed in detail. Another diagram shows the basic elements of the indicator, and a typical indicator card is shown. A. S.

Safety Precautions.

1744. Standpipes for fighting fires in multi-storey buildings. M. Freund. *Heating & Ventilating*, May 1950, **47** (5), 70.—Fire-fighting equipment for buildings can be generally classified in one of the following groups : (i) fire hydrants outside the buildings, (ii) standpipe systems within the buildings, (iii) sprinkler systems, (iv) portable hand extinguishers, (v) mobile (wheeled) extinguishers. With buildings of large area, height, and number of stories it is necessary to have within each building a large supply of water for fighting fires quickly and effectively. The two main types of fire-fighting system under these conditions are the standpipe and hose system and the automatic sprinkler system. The design of standpipe systems is such that they can be used by fire departments and trained personnel in general, by occupants of buildings as first-aid

fire protection, and for both these classes of service. This indicates the importance of designing, installing, and maintaining such systems. The principles and methods to be followed in planning and installing standpipe systems are described in detail. The description includes roof tanks, zoning, and fire pumps, and sketches give details of single and double standpipe systems supplied from a roof tank. Other water supplies for standpipes are discussed. A. S.

1745. Increased production and the safety factor. Anon. *Mech. World*, 2.6.50, **127** (3307), 620.—When it is desired to step-up production much time and thought is devoted by plant engineers and production management to plant and labour efficiency to obtain max output. Design, planning, tooling, material supply, shop loading, etc., are all closely examined with a view to economy of labour and methods. What is often forgotten is the vast annual saving that is yet to be achieved throughout the country in the reduction of industrial accidents with their inevitable loss of output. An industrial accident in any factory affects production far more seriously than is generally realized. Workers in vicinity of accident stop work to go to assistance of their fellow-worker; the machine involved in the accident may have to be taken out of service for inspection and investigation; after consultation, modifications to the machine may be necessary and valuable time spent in fitting new safety appliances, repositioning controls, re-arranging lighting, etc. Furthermore, an accident causes a drop in morale which may have far-reaching consequences as far as output is concerned. A safety officer would probably observe potential source of danger and eliminate risk of injury, and consequent production loss. A number of simple safety precautions are described. A. S.

Miscellaneous.

1746. 1949 : A year of progress in chemical industry development. M. Pescatello. *Chem. Ind.*, May 1950, **66** (5), 670.—A survey of the marketing operations of the major U.S. chemical manufacturing firms during 1949. O. M.

1747. State of the industry—(Chemical Engineering's 27th Annual Review). Anon. *Chem. Engng*, 1950, **57** (2), 91–123.—An economic survey of the chemical industry in 1949 includes reference to coal chemicals, benzene, synthesis gas possibilities, coal hydrogenation, shale-oil utilization, petroleum chemical by-products, and cracking progress. R. G. T.

1748. Status of thermodynamics in the petroleum industry. B. H. Sage. *Industr. Engng Chem.*, 1950, **42** (4), 631–9.—The importance of thermodynamics in petroleum engineering is connected with the prediction of heat and work corresponding to changes of state and with determination of chemical potential of a phase as a function of state. The relation of such calculations are shown, and a brief account given of methods of obtaining thermodynamic properties of pet compounds and mixtures from experimental data. Thermodynamic measurements for the lighter paraffin hydrocarbons are reviewed, and the author discusses the possibilities of further advantageous experimental work. An extensive bibliography is appended. R. G. T.

1749. Applied mathematics saves research time and materials. W. L. Gore. *Chem. Ind.*, May 1950, **66** (5), 678.—It is shown that statistical design of experiments can result in more efficient operation by supplying required information from the minimum number of laboratory tests. Various applications of statistics to industrial problems are illustrated. O. M.

1750. Maintenance in a small refinery. J. S. Pfarr, R. W. Pollard, L. T. Harris, and W. F. Dougherty. *Oil Gas J.*, 18.5.50, **49** (2), 145.—The personnel required and maintenance equipment available in a small refinery are described. Maintenance is listed in three main divisions, housekeeping (cleaning and painting), general maintenance (safety, purchasing, salvage, and construction), and inspection and clean-out, including planned shut-downs. G. A. C.

1751. Levelland gasoline plant. J. E. McCullum, J. M. Cook, and E. W. Kilgren. *Oil Gas J.*, 18.5.50, **49** (2), 119.—The plant at the 70,000-acre field at Levelland, Texas, designed to process 40 million cu. ft. of gas per day is described.

30,000 gal of propane, 40,000 gal of butane, and 60,000 gal of debutanized gasoline per day are extracted. Gas is collected from field separators at 10 p.s.i.g. and delivered to the gasoline plant at a pressure slightly above atmospheric.

Gas-handling facilities include field gas compressors, H_2S removal, and residue-gas dehydration systems.

A two-still system reduces stripping-steam requirements. Product-treating equipment includes mercaptan removal, propane-treating systems, and a copper-chloride treater.

Product storage for five days' production has been installed. G. A. C.

1752. Liquefied petroleum gas sales—1949. K. W. Rugh and E. O. Mattocks. *Chem. Engng*, 1950, **57** (2), 141.—Volume of liquefied petroleum gas marketed in the U.S. in 1949 increased by 8·5%. The increase in the various consuming sections—domestic, chemical manufacturing, industrial fuels, and gas manufacturing—is discussed.

R. G. T.

1753. Use of periodicals in petroleum research. B. G. Hardie and M. J. Voigt. *Oil Gas J.*, 18.5.50, **49** (2), 121.—A study of the actual use of periodicals in the field of petroleum is presented. Tables show subject field, total periodicals, and references, and percentages of periodicals and references. Analysis shows that the petroleum periodicals are referred to only four times out of ten; pure science, principally chemistry periodicals, three times, and the remaining three out of ten concern periodicals in the other engineering fields, including chemical technology.

Only 7% of engineering references date back to 1931. With pure science 30% are before 1931.

Little use is made of Russian articles. G. A. C.

1754. Oil problems at the United Nations scientific conference. I. Petroleum prospecting and production. L. Jacqué. *Rev. Inst. franç. Pétrole*, 1950, **5**, 127–39.—A review of communications presented at the conference (Lake Success) of Aug. 17–Sept. 6, 1949. Main points of papers dealing with oil reserves, prospecting, drilling, production and secondary recovery oil shale, are outlined. A list of papers of oil interest read is given. V. B.

1755. Oil problems at the United Nations scientific conference. II. Petroleum as an energy source. F. Picard. *Rev. Inst. franç. Pétrole*, 1950, **5**, 159–67.—A review of papers. Main uses of energy are domestic and industrial heating and power production. Fuel efficiencies at various stages (production, transportation, utilization) are considered. Economic efficiency may vary from purely engineering efficiency, due to financial factors (taxation, maintenance costs); thus in France use of heavy oil for tractors is only of advantage if operation time >1300 hr/year. Factors governing efficiency of fuel utilization in various types of power unit are outlined. Spark-ignition engines total 64×10^6 units developing 6×10^9 h.p. C.I. engines number $1{\cdot}4 \times 10^6$ having 10^8 h.p. Jet engines and gas turbines are briefly discussed. Most effective power units and fuels for various purposes are tabulated, but extraneous economic and political factors frequently impose use of a fuel or engine other than that most desirable on purely scientific considerations. V. B.

1756. Automatic boiler control. R. Hammond. *Chem. Prod.*, May 1950, **13** (6), 223.—Developments in automatic control have now reached the stage where it can be applied to a very wide variety of operations. Boiler control is an important example of this since, in the past, using manual control in conjunction with the minimum of instrumentation has resulted in inefficient operation. A description of the instrumentation at the M.O.R. plant at Partington is given. In addition, based on an estimate made by Monsanto in America, the economic advantages of instrumentation are illustrated. O. M.

1757. How to dispose of acid wastes. J. E. Cooper. *Chem. Ind.*, May 1950, **66** (5), 682.—Two main methods are available for the disposal of acid wastes. They are dilution and neutralization. The first method is the simplest and least expensive, but depends on the availability of a sufficiently large volume of receiving water. The advantage of the neutralization method is that it eliminates the need for acid pumps in the disposal system. O. M.

1758. Bacterial oxidation of petroleum and its migration in natural watercourses. A. A. Voroshilova and E. V. Dianova. *Mikrobiologiya*, 1950, **19**, 202–10.—Oil-pollution of river water is discussed, and the processes through which pet passes after discharge into a river are considered. Three main stages can be distinguished: (i) ærobic bacterial oxidn on the surface, (ii) anærobic bacterial oxidn on the river bed, to which the oil sinks after lighter fractions have been lost by evaporation and oxidn, and (iii) further ærobic oxidn on surface, to which oil is carried by gas rising from river bed. Water is essential for bacterial oxidn of pet, and such oxidn only occurs at oil/water interface. Presence of oil on water greatly increases (by a factor of up to 35) bacterial count in surface layers of the latter; figures for Moscow river and laboratory experiments are given. Gas rising from Moscow river varies from 150 ml (winter) to 2000 ml. (summer) per m^2 of river bed, such gas (largely CH_4) carries with it up to 35 mg of oil per 100 ml. Anærobic oxidn of pet is largely carried out by denitrifying and desulphurizing bacteria; resulting formation of H_2S is particularly obnoxious during winter, when ice prevents escape of this gas to air. As bacterial processes of oil oxidn are slow, tests on river water should be prolonged and oxygen demand should be measured over longer than 5 days. V. B.

1759. Aerosols prove worth in greenhouse pest control. R. A. Fulton and F. F. Smith. *Chem. Ind.*, Apr. 1950, **66** (4), 539.—Aerosols of the type used in households have been found unsatisfactory for use in greenhouses due in part to their inability to give complete pest control therein and in part to plant damage caused.

It has been found that a 5% solution of hexaethyl tetraphosphate, whose principle active ingredient is tetraethyl pyrophosphate, in methyl chloride, as propellent, gave excellent results and that plant damage was negligible provided application was carried out at 75°–85° F. Parathion aerosols have been developed to supplement those based on tetraethyl pyrophosphate, but cannot yet be recommended for use on greenhouse vegetables after the edible part has been formed.

Newer insecticides for this application are octamethyl phosphoramide, a systemic insecticide, and *p*-chlorophenyl, *p*-chlorobenzene sulphonates, both of which are soluble in methyl chloride but are still being examined experimentally.

When applying phosphorous-containing insecticides, protective clothing should be worn, since they are absorbed through the skin. O. M.

BOOK REVIEWS.

A New Dictionary of Chemistry. 2nd Edition. Edited by S. Miall and L. M. Miall. London : Longmans, Green & Co., 1949. Pp. ix + 589. 60*s*.

The first edition of this small chemical dictionary was published in 1940, and the present, second edition, has been revised and corrected with a number of new articles added by the editors and other contributors. There is a mass of information in this book, some of it of everyday importance, while other items will, one might expect, be turned up deliberately on but few occasions. Who, however, finding across his path such entries as cellarius tourill, nitrogen mustards, haptens, and baptisin can, unless he already be familiar, pass on without exploring them more fully? Certainly not the reviewer.

Biographical entries are plentiful (about 400 in a total of some 6000 items) and refer both to bygone chemists and to some who are still with us. Those of the former are much safer material; it is less difficult to choose which to include and which must be omitted, and it is, in general, much easier to bring and keep them up to date.

The general level of accuracy of the information is high, but some of the comparatively few entries of direct petroleum interest leave something to be desired. For example, the information under aviation petrol, char value, highest useful compression ratio, and octane number is either not quite accurate or a little misleading.

On more general matters of chemical interest, this book has a very real value for quick reference, and may be expected to enjoy a continued and well-earned popularity. E. B. E.

Phenolic Resins. P. Robitschek and A. Lewin. London : Iliffe & Sons, Ltd. (for *British Plastics*), London, 1950. Pp. 261. 30*s*.

The authors' aim in writing this book is to integrate theoretical knowledge and industrial practice. After introductory chapters on the historical background and on the raw materials required for phenolic resin manufacture, three chapters are concerned with theoretical considerations—"Chemistry," "Physics," and "Kinetics." Since these three chapters represent only thirty-six pages a high degree of compression and selection has been involved. The criterion adopted is wisely to discuss only those theories or reactions which have found reasonable substantiation in practice. Thus the basic reactions leading to the formation of novolaks and resols are discussed, and the essential points arising from the very significant work of Zinke, Hultzsch, von Euler, and their respective co-workers on the hardening of "model" phenols are considered in very little space. This is perhaps unfortunate, particularly since von Euler's work is mainly published in *Arkiv. Kemi Mineral. Geol.*, which may not be readily accessible to a number of readers. A fuller treatment of these curing reactions has been given in Carswell's "Phenoplasts" (High Polymers, Vol. VII, Interscience, New York, 1947), a book which, strange to say, gains no mention in this text. The chapter on physics discusses briefly the properties of resin solutions, the optical, electrical, and mechanical properties of phenolics, and the theories of the fine structure of the resins. The actual measured properties of miscellaneous types of p/f resins are set out and discussed in the penultimate chapter. In the section on kinetics the general experimental methods are mentioned and the effect of various reaction conditions, *e.g.*, type of solvent, concentration, type of catalyst, p/f ratio, temperature, and type of phenol are discussed.

Seven chapters—about 120 pages—devoted to the industrial manufacture of resins, etc., follow. These are concerned with the preparation of moulding compositions, casting resins, laminates, pulp-resin preforms, resin-wood products, and moulding techniques. A brief section on the lab-scale preparation of resins is a welcome feature. For examples of actual manufacturing formulæ the authors have drawn on German information from C.I.O.S. reports, and each section is well illustrated with photographs and clear line diagrams. In these chapters there is a

lot of useful information logically set out and clearly written. There are, however, some omissions. Thus the production of oil-soluble or drying oil-modified phenolics for use in protective coatings is hardly mentioned, and no reference is made to the phenol-furfural resins which have for some time been established in the United States. Furthermore, mention of the phenolic resin/acrylonitrile rubber compositions having improved toughness and impact strength would not be out of place.

The remaining chapters are concerned with the testing and general applications of phenolic resins. The chapter on testing refers to the various sources of test specifications, but is mainly concerned with the meaning of test results. In this connexion a few pages are devoted to elementary statistical analysis of results. Though there are a number of readily available books and papers on this topic, the inclusion of these pages is an excellent idea. The final chapter on applications is a brief but useful survey, though it could perhaps be made more useful by giving some idea of the relationship between phenolics and other thermosetting materials such as the urea and melamine resins.

The authors claim that the book is not intended to be a catalogue or encyclopædia, but an explanatory digest. It will indeed be useful to those who already have some experience of phenolic resins, and will also serve to introduce the subject to those who, generally interested in plastics, wish to gain more detailed information concerning these particular materials.

The book is attractively printed and well bound. It appears to be reasonably free from misprints, though they are not absent. There is, for instance, an odd phenol molecule in Fig. 8*b* (p. 39) which does not belong to the equation, and in one place at least there is a name misspelt (*cf.* Nasan for Nason in ref. 16, p. 241).

P. G. C.-W.

BOOKS RECEIVED.

American Society for Testing Materials: Proceedings. Vol. 49. Philadelphia: The Society, 1949. Pp. xi + 1240.

Includes all reports and papers offered to the Society during 1949, together with discussion. The author and subject indexes carry, in addition, references to papers not included in the *Proceedings*, which have been published in the *A.S.T.M. Bulletin* or as Special Technical Publications.

Among the Committee Reports published are: D-2 on Petroleum products and Lubricants; D-3 on Gaseous Fuels; D-4 on Road and Paving Materials; D-8 on Bituminous Waterproofing and Roofing Materials; D-9 on Electrical Insulating Materials; D-13 on Textile Materials; and D-15 on Engine Antifreezes.

Technical papers include "Subsurface explorations by geophysical methods," by E. Raymond Shepard, and "Evaluation of metal transformer oil during service," by Frank M. Clark.

1949 Book of A.S.T.M. Standards Including Tentatives. Part 3. Cement, Concrete, Ceramics, Thermal Insulation Road Materials, Waterproofing, Soils. Philadelphia: The Society. Pp. xxix + 1344.

Part 3 of the American Society for Testing Materials' triennial publication, which now appears in six parts. The section on Bituminous Materials for Highway Construction, Waterproofing, and Roofing includes thirty-four specifications and forty-two methods of test.

1949 Book of A.S.T.M. Standards, Including Tentatives. Part 6. Electrical Insulation, Plastics, Rubber. Philadelphia: The Society. Pp. xxx + 1374.

Publication of this volume completes the 1949 edition of the A.S.T.M. six-part Book of Standards. Materials subdivisions are Electrical Insulating Materials, Plastics, Rubber Products, Thermometers, and General Testing Methods. The section on Mineral Oils for Electrical Insulation includes methods of testing and sampling insulating oils; testing dielectric strength of insulating oil of petroleum origin; saponification number of petroleum products by colour-indicator titration.

Tube Works Gauges and Gauging Practice. Compiled by F. W. Clark. London: Stewarts and Lloyds Ltd., 1950. Pp. 64. 5*s*.

Designed primarily for use by trainees at the works of its publishers, it is suggested that the book may be of value for general reference. Among the appendixes is a list of reference books and of British and American Standards relating to gauging and screw-threads.

The Analysis of Asphalt Paving Mixtures. Asphalt Roads Association. London: The Association, 1950. Pp. 38.

In an investigation on current methods of analysis of asphalt paving mixtures in relation to B.S. 598, the A.R.A. carried out 254 analyses on four samples in eleven laboratories. Seven different methods of analysis were used—funnel, hot extractor, centrifuge, methylene chloride, pressure filter, Rebstein extractor, and Soxhlet extractor. Details of the methods are given, together with analytical and statistical results.

No evidence emerged for replacing the funnel method as the B.S. referee method, but it was indicated that if a "rapid" method was needed, consideration should be given to the methylene chloride method.

Proceedings of the Automobile Division of the Institution of Mechanical Engineers, 1947–48. London: The Institution, 1950. Pp. 166.

Contains papers, mostly on the design and production of engines and vehicles, read before the Automobile Division during the session 1947–48.

Modern Methods of Organic Solvent Manufacture. J. L. Edgar. London: Royal Institute of Chemistry, 1950. Pp. 21. 3*s*. net.

A lecture delivered to the London S.E. Counties Section of the R.I.C. in March 1949.

Drilling and Sampling of Bituminous Sands of Northern Alberta. Ottawa: King's Printer, 1949.

Vol. I. Results of investigations 1942–1947. Pp. v + 36. 25 cents.
Vol. II. Detailed drilling and sampling records. Pp. 670. $5.00.
Vol. III. Cross-sections and plans of areas drilled. 80 sheets. $10.00.

As a safeguard against a critical shortage of oil during the war, the Canadian Government undertook a systematic investigation of the bituminous sands of Northern Alberta. A large number of bores were sunk to obtain samples of the sands, which were then examined in the laboratory.

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The second volume gives detailed logs of all the wells, together with analyses of the bitumen content of each sand and a screen analysis of its mineral matter. Volume III consists entirely of maps and cross-sections of the areas in which the drillings were made.

The Scientist's Ready Reckoner. W. Roman. The Hague: Dr W. Junk, 1950. Pp. viii + 142.

A comprehensive set of tables for laboratory use, covering atomic weights, weights of molecules and radicals, gravimetric and titrimetric factors, specific gravity for liquids, and temperature conversion. In most cases the logarithm of each factor is given, and four- and five-figure logarithm tables are appended.

This book should prove of practical value in the laboratory in rendering unnecessary many calculations.

The German Coal Tar and Benzole Industries during the period 1939–1945. A. L. Deadman and G. H. Fuidge. London: H.M.S.O., 1950. Pp. 181. 5*s*. 6*d*. net.

This survey is No. 25 in the B.I.O.S. series and contains a mass of data on the coal-tar and benzole industries of Germany, particularly in pre-war and prior to damage during the war. The information should prove of considerable value.

A good piece of work has been done in collating information contained in some fifty-two intelligence reports previously issued in the B.I.O.S., C.I.O.S., and F.I.A.T. series and also nearly ninety in the Foreign Documents series.

Financial Analysis of Thirty Oil Companies for 1949. Joseph E. Pogue and Frederick G. Coqueron. New York : Chase National Bank Petroleum Department, 1950. Pp. 16.

A summary review in tabular form of the operations of the American petroleum industry for the year 1949 as indicated by the combined figures of thirty oil companies.

1950 Appendix to A.S.T.M. Manual of Engine Test Methods for Rating Fuels. Philadelphia : The Society, 1950. Pp. 27. $1.00.

Issued in January 1950 this appendix includes changes through 1949 in the "A.S.T.M. Manual of Engine Test Methods for Rating Fuels." Various new tables have been added, and existing tables amended, and there have been editorial changes. The 1940 Appendix is an important addition to the 1948 Manual, and is useful only in connexion therewith.

Modern Applications of Liquid Fuels. George Sell (editor). London : The Institute of Fuel—The Institute of Petroleum. 1950. Pp. viii + 489. £1 1*s*.

The full report with discussion of the conference held at Birmingham in September 1950, when nineteen papers on fuel efficiency in various industries were presented.

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JENKINS, E. H.
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O'CONNOR, D. D. T.

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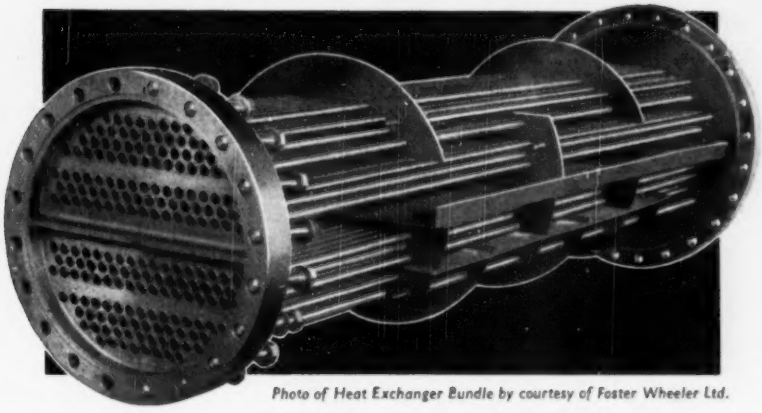

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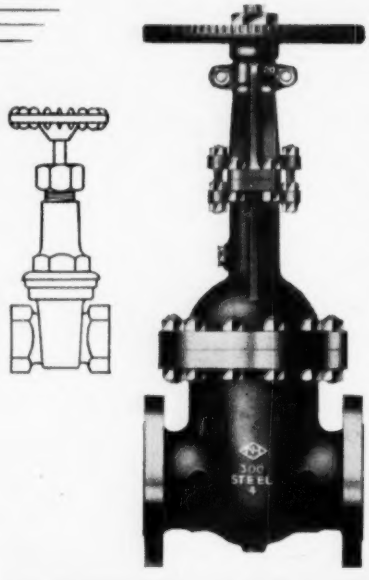

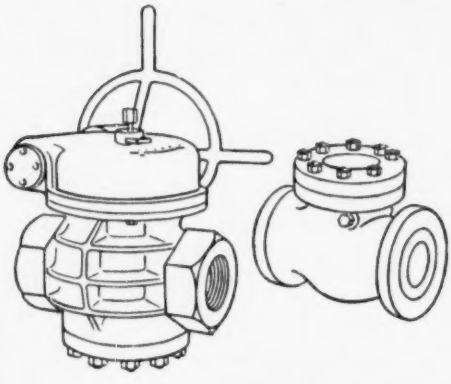

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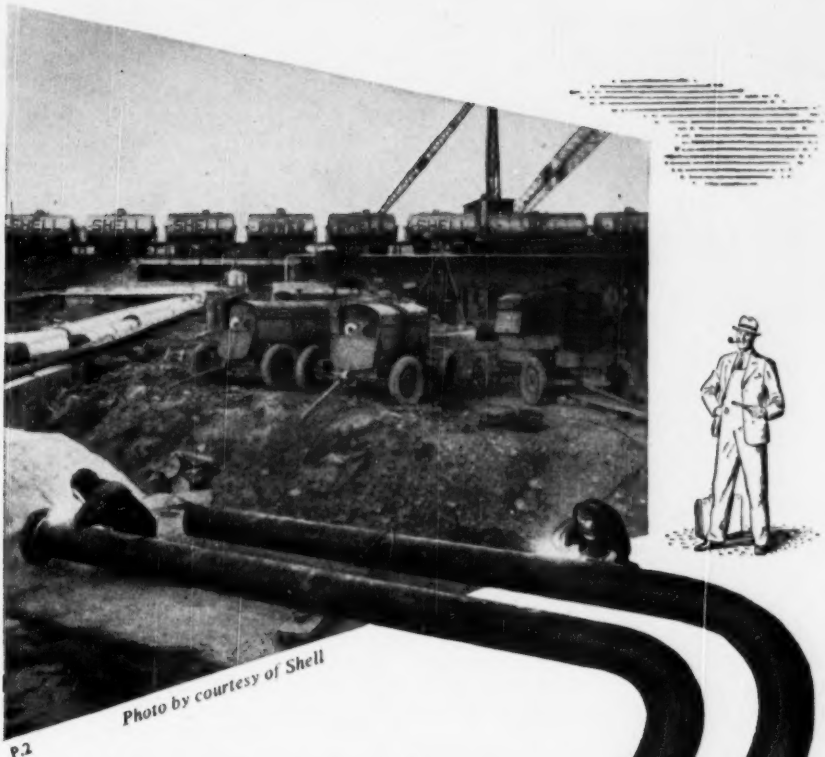

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P.2

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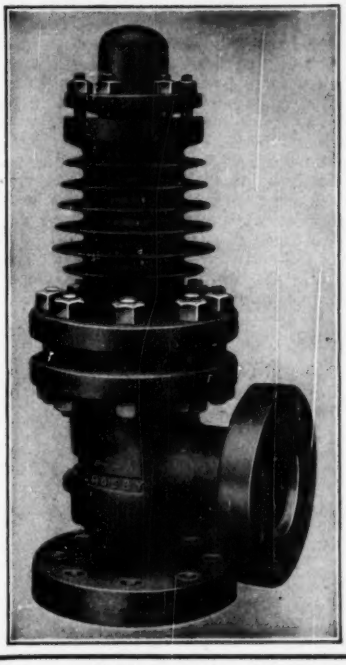

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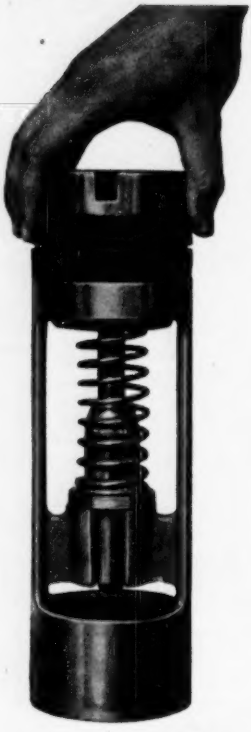

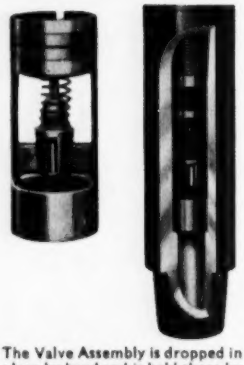

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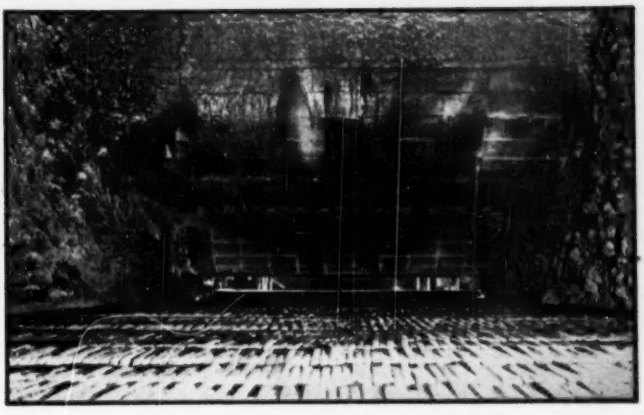

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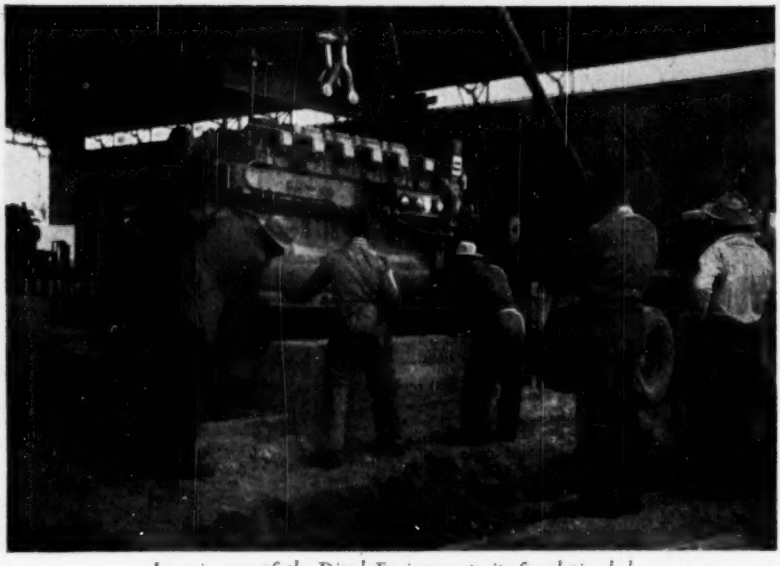

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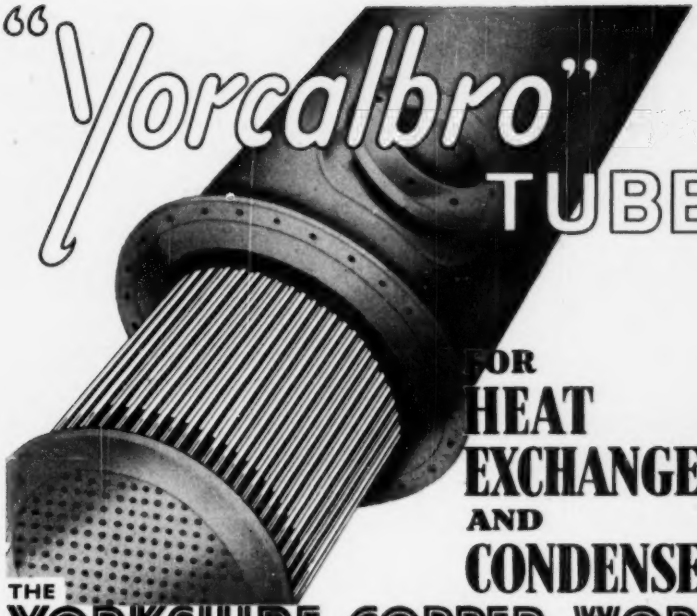

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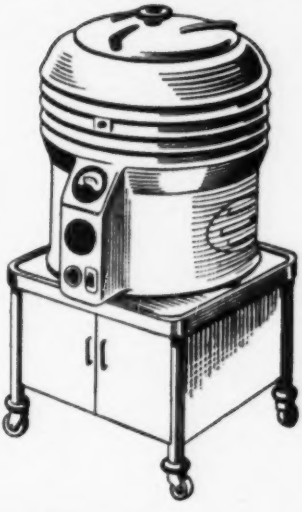

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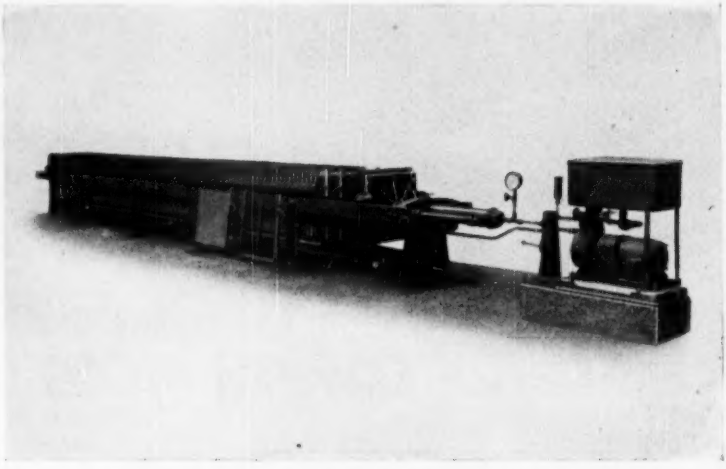

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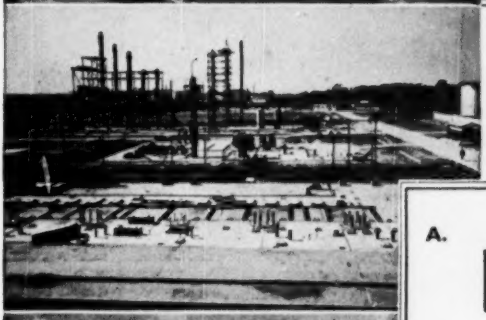

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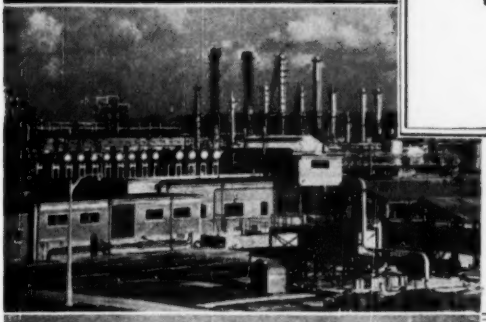

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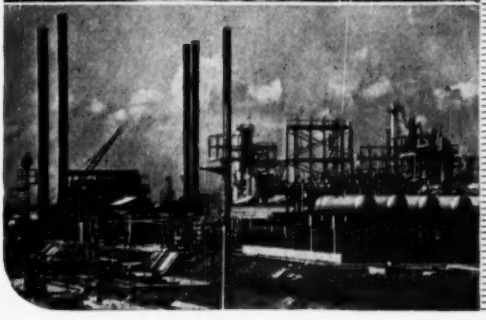

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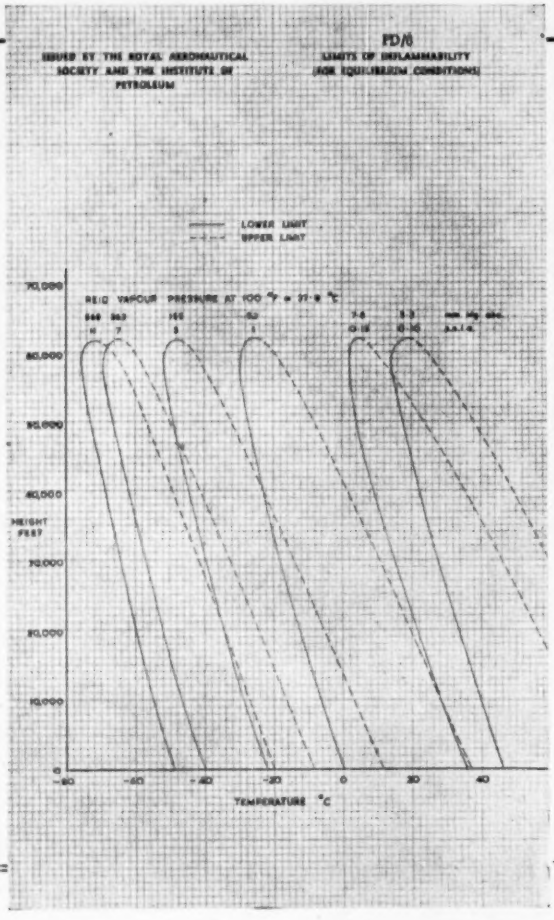

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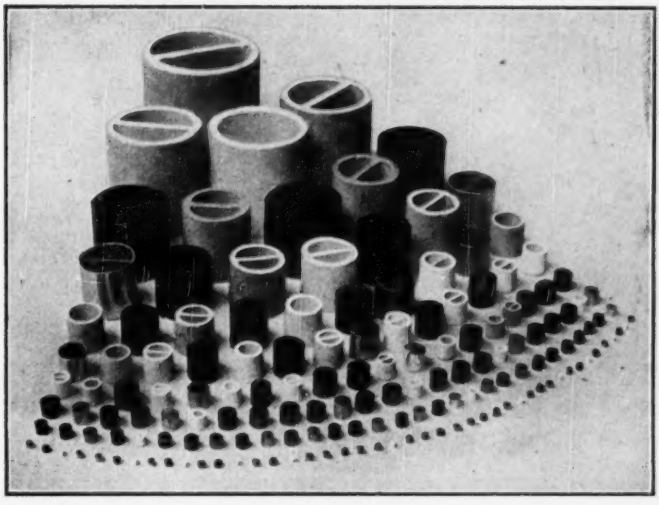

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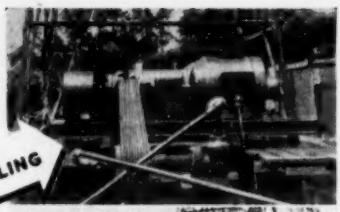

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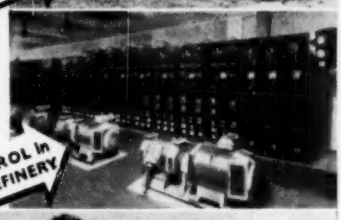

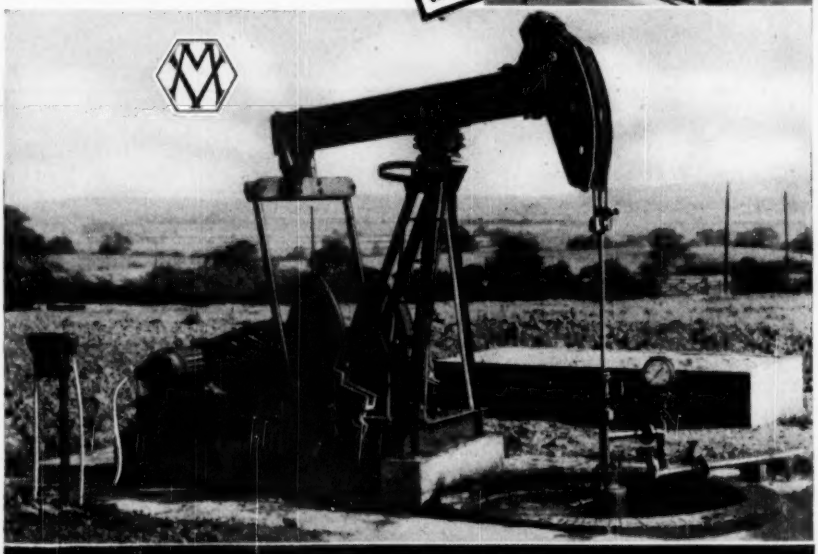

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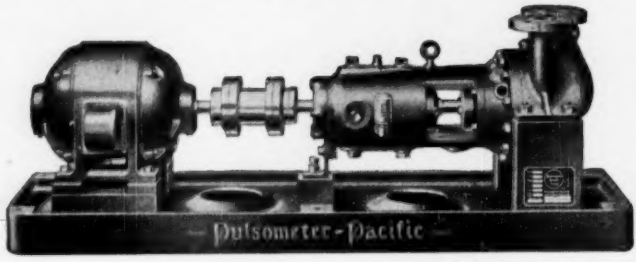

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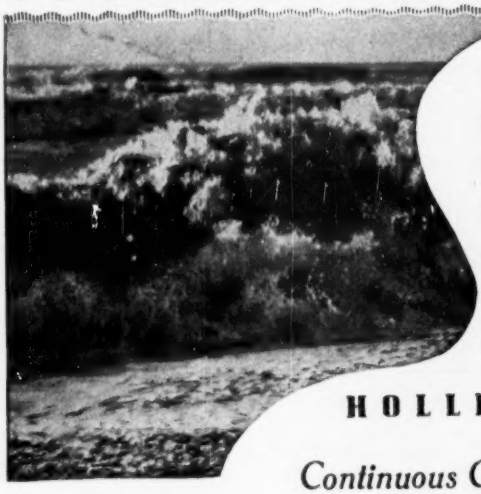

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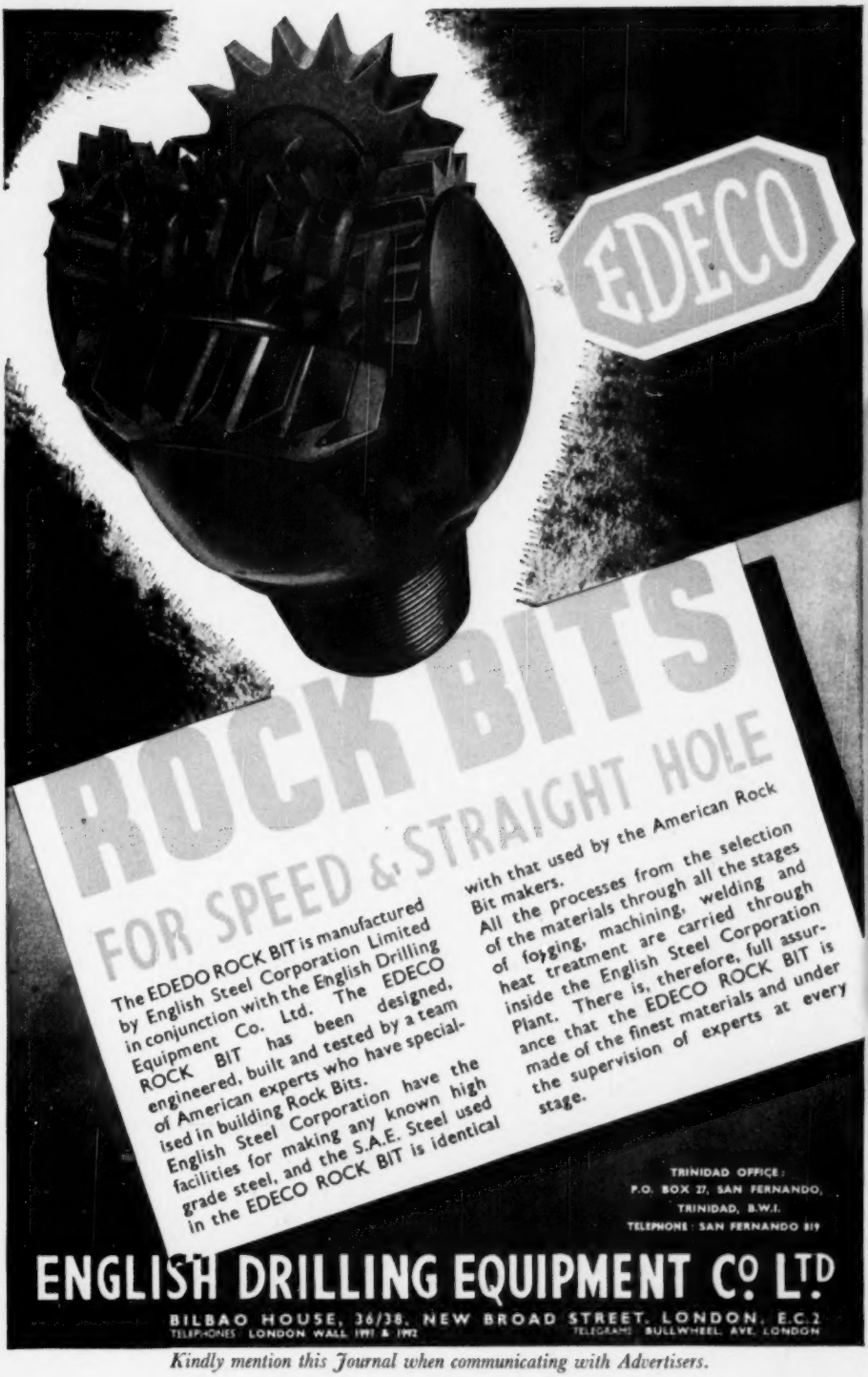
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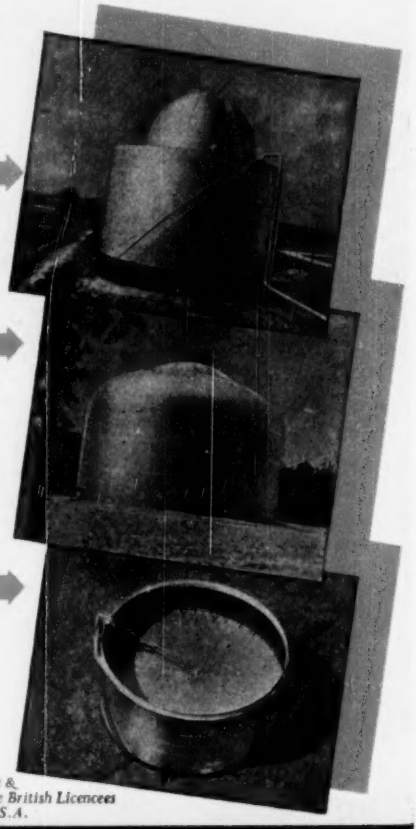

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